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REPORT ON THE PREVALENCE OF SOME PESTS AND DISEASES IN THE WEST INDIES DURING 1915.

(*Compiled from the Reports of the principal local Agricultural Officers*)

This is the seventh report of this series, the latest previous one, that for 1914, appearing in the *West Indian Bulletin*, Vol. XV, p. 121. The present report covers the period January to December 1915, and has been prepared in the same way as previous ones, from information supplied by the Agricultural Officers in the several islands.

ENTOMOLOGIST'S VISITS. During the year the Entomologist visited Grenada in February and March, and Montserrat in July.

The principal object of the visit to Grenada was to study the conditions which attend and influence the outbreaks of the cacao thrips (*Heliothrips rubrocinctus*). Abstracts of the report on this visit have been published in the *Agricultural News*, Vol. XIV, p. 314, and in the *Review of Applied Entomology*, Vol. III (1915), p. 173.

The conclusions arrived at as a result of observations made during the course of this visit may be very briefly stated as follows. Cacao thrips is not in itself a pest, but always an indication of some unfavourable condition affecting the health and vigour of the cacao trees. These unfavourable conditions may result from unsuitable soil, lack of shade, insufficient or improper drainage, exposure to wind, root disease, or in fact anything which interferes with the growth and proper development of the cacao trees. Measures which tend to correct these unfavourable conditions will check the attacks of thrips, and the agricultural practices which prevent their recurrence and maintain a healthy condition in the cacao trres will prevent attacks by this insect. A severe attack of thrips should be regarded as a certain indica-

tion that the trees are suffering from some unfavourable condition which should at once be sought out and corrected.

The second of these visits, that to Montserrat, in July, had for its object the making of certain observations on the condition of the lime cultivation in that island. An abstract of the report on the observations made and conclusions arrived at during that visit was published in the Report on the Experiment Station, Montserrat, for 1915.

MYCOLOGIST'S VISITS. The Mycologist visited Grenada in February and March in company with the Entomologist, and paid special attention to the subject of Rosellinia root disease of cacao. The type due to the species *R. Pepo* was found to be very destructive in some upland cultivations visited, and a hitherto unrecognized type, due to a species not yet determined, was found occasionally in the drier coastal districts. Attention was given to the question of fungus control of scale insects, and the effects of the practice of lopping trees to get rid of black blight. The report made was printed and circulated locally.

A brief visit was paid to Montserrat, in July. The conclusion was reached that the dying back of the roots, which is a common feature of the failure of lime trees in that island, is brought about by weakly parasitic fungi which enter by way of wounds made by the grubs of the Exophthalmus weevil when the trees are not sufficiently vigorous to heal them quickly. The die back of the branches appears to be largely due to a Diplodia, probably *Lasiodiplodia Theobromae*, which again is not able to attack vigorously growing trees. It is the opinion of the Mycologist that close shelter to conserve the humidity of the air, and a soil covering to prevent drying out of the upper layers of the soil would enable the trees successfully to resist both forms of disease. The necessity of these measures is due to the exposure and low rainfall of the districts under limes as compared with the cultivation of Dominica and St. Lucia.

In July, Dominica was visited for a continuation of the study of root diseases of lime trees. During the year the results thus obtained were put forward in Pamphlet No. 79, entitled 'Diseases of Lime Trees in Forest Districts'. Observations were also made on the dying out of the lime trees on certain old-established fields. No specific disease was found at work : the trees seem to have reached the limit of their existence under the system of cultivation followed.

CLIMATE.

GRENADA. Ideal agricultural weather since May. Rainfall plentiful and well distributed. Absence of injurious heavy winds.

ST. VINCENT. Wet season. Rainfall unusually heavy, 122·74 inches at Botanic Station.

ST. LUCIA. 1915 proved to be the wettest year on record since 1895, and it followed the driest year (1914) on record for twenty-five years. The rains were very beneficial to the cane cultivation in the usually dry southern coastal districts, but it proved too much for similar cultivation on heavy clay soils.

No increase in fungoid diseases generally was noticed, and the absence of serious outbreaks of scale insects was probably due to the favourable conditions for the development of the parasitic fungi.

Rainfall at Botanic Gardens, Castries, 135·70 inches; at Experiment Station, Choiseul, 63·81 inches.

DOMINICA. The climate during the year left much to be desired. A hurricane passed over the island in August and inflicted considerable damage, and a strong gale followed soon after in September. The rainfall was excessive, amounting to 100 inches in Roseau, retarding many agricultural operations.

MONTSERRAT. Ample rainfall was obtained from April to the end of the year. Very high winds during part of the cotton-growing season. Rainfall at Grove Station, 74 inches.

ANTIGUA. A good year from an agricultural point of view was experienced. More than 63 inches of rain fell at the Botanic Station.

ST. KITTS. The rainfall for the past year was about 60 inches in the valley district and 90 inches in the northern district, being 12 inches above the average rainfall in the former district and 35 in the latter.

In consequence of this the cane crop will be a heavy one, and the cotton much below the average.

NEVIS. The weather, on the whole, was fairly moist, although the total rainfall (52·10 inches) for the year was 1·45 inches below that of last year. The showers were more in season, and more benefit was derived from them. The storm in August did great damage to the cotton crop. On some estates in exposed situations the crop was almost ruined.

VIRGIN ISLANDS. Though the total rainfall recorded (63·01 inches) was above the average, yet crops such as cotton, ground provisions, canes, etc., suffered on account of a summer drought. The months of July, August, September, and part of October were dry.

PART I.—INSECT PESTS.

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SUGAR-CANE.

MOTH BORER (*Diatraea saccharalis*).

ST. VINCENT. Generally present, locally severe.

ST. LUCIA. General in cane fields. No serious outbreak.

ANTIGUA. Prevalent in all cane fields

MONTSERRAT. Very general on cane plot in Experiment Station, 1915. No observations elsewhere.

ANTIGUA. Common throughout island.

ST. KITTS. Moth borer can be found in any field of canes but there has been no severe attack during the year.

NEVIS. Fairly abundant on all estates.

VIRGIN ISLANDS. Generally distributed; does a good deal of damage.

WEEVIL BORER (*Sphenophorus sericeus*).

ST. LUCIA. General in cane fields. No serious outbreak.

NEVIS. Found in a few places, not very plentiful.

VIRGIN ISLANDS. No observations made.

ROOT BORERS (*Diaprepes* and *Exophthalmus*).

ST. LUCIA. Present but no serious damage done.

MONTSERRAT. No observations.

ANTIGUA. *E. esuriens* found in cane fields in southern part of island.

ST. KITTS. In certain districts the root borers both *Lachnosterna patruelis* and *Exophthalmus esuriens* have been present and done much damage, especially on canes like B. 208, which is very susceptible.

On one estate in the northern district, *E. esuriens* was found doing much damage, and planters have been advised to take steps to collect the beetles.

NEVIS. Diaprepes not observed.
E. esuriens not observed attacking canes, but the adult insect may be found on hedges near cane fields

VIRGIN ISLANDS. Diaprepes. No observations made. *E. esuriens* present, adults attack various plants.

HARD BACK GRUBS.

ANTIGUA. Considerable amount of interest is being taken in connexion with these grubs (*Lachnosterna* sp.) at the present time. Very common in heavy lands of Central Plain. Considerable amount of damage being done by this pest.

ST. KITTS. Grubs of the black hard back (*Ligyrus tumulosus*) are found in large numbers, but no damage is recorded. Grubs of the brown hard back (*Lachnosterna patruelis*) are prevalent and do damage in certain districts.

NEVIS. *Ligyrus tumulosus* found in many cane fields.

VIRGIN ISLANDS. The rhinoceros beetle (*Strategus titanus*) recorded.

WHITE ANTS (TERMITES).

ANTIGUA. These insects are found commonly in fields in central part of island.

ST. KITTS. These insects have been found on one estate during the year, and poison bait applied with success. At Pond estate no record of their doing any damage.

MISCELLANEOUS INSECTS.

ST. VINCENT. Mealy-bug.

ST. LUCIA. The larvae of the corn ear-worm (*Laphygma frugiperda*) were reported attacking sugar-cane in St. Lucia, in June. The insects were controlled by the application of Paris green and lime.

COTTON.

COTTON WORM (*Alabama argillacea*).

ST. VINCENT. No outbreak.

ST. LUCIA. Very severe in all patches of cotton.

MONTSERRAT. First reported attacking two months old plants in June 1915, and generally distributed and severe all through season. Expense of control particularly heavy on account of wet season, and showers washing off poison. Supplies of Paris green ran short but not to result in very severe damage.

ANTIGUA. Common throughout growing season. Considerable amount of damage done where attacks neglected.

ST. KITTS. The cotton worm was very severe in its attacks in certain localities, but was kept in check by poison.

NEVIS. Very abundant throughout the island causing a certain amount of damage. Fields were attacked as early as June this season.

VIRGIN ISLANDS. Generally distributed, attacks locally severe.

BOLL AND CORN EAR WORM (*Heliothis* and *Laphygma*).

MONTSERRAT. *H. obsoleta.* A few cases reported, but little damage done.

ANTIGUA. Fairly common, did but little damage.

NEVIS. Not observed.

The cotton worm was present on old cotton in January in Antigua, Nevis, and the Virgin Islands. The attacks on the year's (1915-16) crop began in June in Montserrat, St. Kitts, and Nevis, and in July in Antigua. In St. Vincent, although this insect did not occur as a pest during the year under review, it was observed in June. This occurrence in June and July constitutes a record for the appearance of the cotton worm in these islands: in Montserrat and Antigua the attack continued right through to the end of the year. In St. Kitts it is mentioned only in June, July and October, while in the Virgin Islands the 'worst attack on record' occurred in November and December, and continued into January 1916.

COTTON STAINERS.

ST. VINCENT. Generally present, locally severe.

ST. LUCIA. Present but not serious.

MONTSERRAT. Appeared in small numbers in July, in a few localities. Fairly general in November in spite of efforts to control; very little damage to main crop.

ANTIGUA. Less prevalent than in previous seasons.

ST. KITTS. Cotton stainers have been present but there has been no actual damage, the cotton plants being turned in after first picking.

NEVIS. Stainers were not as plentiful as in the past seasons.

VIRGIN ISLANDS. Local attacks.

Cotton stainers were present in some numbers in the Virgin Islands during January, February, March, and April, being reported in the last of these months as common all over the island (Tortola). In Antigua they were fairly common on old cotton during March. In Nevis they were not reported until November.

In Montserrat the Curator sent out a circular to planters during June with regard to taking measures to control cotton stainers when they should make their appearance. In July they were abundant, as evidenced by the fact that there were collected on ½-acre of cotton in a space of two weeks 7,000 cotton stainers. In August, they were reported as being abundant in a few localities, and in November as being abundant in some districts and controlled by collection in others. During December they became abundant in most parts of the island.

SCALE INSECTS.

BLACK SCALE (*Saissetia nigra*).

WHITE SCALE (*Hemichionaspis minor*).

ST. VINCENT. Black scale. Locally severe.

MONTSERRAT. Black scale. A few sporadic cases only.
White scale. Not observed.

ANTIGUA. Black scale. Found on old cotton.
White scale. Found on old cotton.

NEVIS. The white scale was observed in a few fields, but not occurring to any great extent.

VIRGIN ISLANDS. None observed.

FLOWER-BUD MAGGOT (*Contarinia gossypii*).

MONTSERRAT. Not reported.

ANTIGUA. Not seen during year.

NEVIS. Not observed.

VIRGIN ISLANDS. Of doubtful occurrence (since confirmed).

LEAF-BLISTER MITE (*Eriophyes gossypii*).

ST. VINCENT. Rather more prevalent, due it is considered to less attention having been paid last season to the destruction of old cotton plants.

ST. LUCIA. General, particularly on Upland stumps.

MONTSERRAT. Not more prevalent than usual, but perhaps less so, and no damage resulted.

ANTIGUA. Common on old cotton.

ST. KITTS. Leaf-blister mite is always present on mature cotton, but in St. Kitts the plants are turned under at an early stage and little damage occurs.

NEVIS. Very abundant throughout the island.

VIRGIN ISLANDS. Generally distributed in practically all cotton fields.

Leaf-blister mite was reported as occurring in the Virgin Islands in September, in Antigua and St. Kitts in October, and in Nevis in November.

MISCELLANEOUS INSECTS.

ST. VINCENT. Cryptorhynchus borer at Experiment Station. Thrips attacked bolls. The bronze beetle (*Colaspis fastidiosa*) occurred and was troublesome, especially in Bequia.

MONTSERRAT. There were very general attacks of aphis during this season, particularly in exposed situations, and the fields so attacked looked sickly. A feature was the general absence of the common red lady-bird; a small dark species the larvae of which has a waxy covering appeared to be the chief control. This species was not identified. Cotton seedlings were attacked by cut-worms in Montserrat and some damage done during May.

ANTIGUA. Isolated attacks of aphis noticed during year.

ST. KITTS. Cockroaches were very prevalent and did much damage to the young plants on one estate. Crickets were present in large numbers on another estate and destroyed the cotton just as the seed was germinating in the land.

NEVIS. Cotton aphis was observed in many of the early fields. Lachnopus was observed in a few fields, but the pest was not so abundant as it was last season.

VIRGIN ISLANDS. The grey weevil, Lachnopus, was observed feeding on cotton.

The year under review seems to have been an unusual one for aphis as for cotton worm attacks. During July aphis was reported from Montserrat and Tortola, and in August the condition in Montserrat was referred to as an unprecedented attack.

During June in St. Kitts there were two unusual insect attacks on young cotton plants.

One of these was the instance of young cotton seedlings being severely attacked by cockroaches resulting in the loss of the stand on a considerable area, and necessitating replanting. The insect concerned in this attack was the common cockroach (*Periplaneta australasiae*). This is the first record of this insect as a pest of growing crops in these islands.

The second of these attacks was that of the common field cricket (*Gryllus assimilis*) attacking cotton in a similar manner. Instances of attacks on cotton by this insect have been observed in St. Kitts before.

CACAO.

THRIPS (*Heliothrips rubrocinctus*).

GRENADA. Present in its usual habitats but less severe than last year.

ST. VINCENT. Generally present, locally severe.

ST. LUCIA. Observed in small numbers, but no attacks recorded

DOMINICA. Generally present in cacao cultivation, and in one instance in sufficient numbers to give some trouble in determining the ripeness of pods.

In Grenada cacao thrips was, in March, stated to have gone off to a considerable extent: in August to be showing strong in one locality: in September to be bad in a few well defined places: and in December to be not much in evidence.

In St. Vincent, thrips was reported to be attacking cacao badly, in May. In August it was reported not to be so bad as in the early part of the year. A parasitic fungus was found attacking thrips, in May. Spraying was reported to be in progress in August.

Mealy-bug and black blight were reported from Grenada in January.

BEETLE (*Steirastoma depressum*).

GRENADA. Locally severe, but normal.

SCALE INSECTS AND MEALY-BUGS.

GRENADA. Occurred during year.

ST. VINCENT. Mealy-bugs generally distributed.

MISCELLANEOUS INSECTS.

GRENADA. Lineless termites. Local.
Acrobat ant. Local.

DOMINICA. The serious attack of root grubs on one of the grafted cacao plots at the Station has been checked by treatment with carbon bisulphide emulsion, and the application of a complete manure. The trouble has not spread during 1915.

Limes and other Citrus.

SCALE INSECTS.

GRENADA. The purple, green, snow, and West Indian red scales.

ST. VINCENT. Generally distributed, severe.

ST. LUCIA. Purple, snow and green scales common throughout island on young trees. Established trees remarkably free.

DOMINICA. On the whole, the island continues to be free from severe attacks of scale insects. This is due largely to the prevalence of the fungus parasites which continue to keep the scales under control. Young lime trees often suffer severely through the attacks of scale insects.

MONTSERRAT. There have not been any severe developments of scales on the cultivation, though areas are still suffering and scale insects appear to be the principal factor.

ANTIGUA. Common in all lime fields. On the whole, less damage done than in previous years.

NEVIS. The green and the purple scales occur to a fairly great extent in all the plantations. The white scale also occurs to a fairly great extent.

VIRGIN ISLANDS. Snow scale. Purple scale.

In Antigua the green scale (*Coccus viridis*) and black blight were reported as common on limes in some districts in March, and the purple scale (*Lepidosaphes beckii*) was increasing. In Montserrat in April, the white scale (*Chionaspis citri*) was reported on limes.

BARK BORER (*Leptostylus praemorsus*).

GRENADA. Of doubtful occurrence.

DOMINICA. Not a serious pest during the year.

ANTIGUA. Of doubtful occurrence.

TWIG BORER (*Elaphidion mite*).

DOMINICA. Often found in isolated instances not in any way serious.

ANTIGUA. Not noticed during year.

NEVIS. Not observed.

ROOT BORER GRUBS (*Diaprepes* and *Exophthalmus*).

ST. LUCIA. One case observed, not serious, as to whether A or B; most probably B.

DOMINICA. Further evidence of considerable damage inflicted by root borers came to the notice of the staff. They often cause a serious set-back to young trees.

MONTSERRAT. No further information accumulated in regard to (*Exopthtalmus esuriens*). A list is appended (page 33)

showing the numbers collected in Grove Station from March 1914 to October 1915. Fairly regular collections were made during the period from October 1914 to October 1915 with a view to finding out the time of the principal emergence of this insect: 70,000 were collected in a few days on one estate, and at the end of May it was reported that 200,000 of these veevils had been collected on this estate.

ANTIGUA. Severe attacks experienced on one estate. Enormous quantities of Exophthalmus beetles caught early in year.

NEVIS. Not observed.

FRUIT FLY AND ORANGE MOTH.

DOMINICA. The orange moth is kept under control by spraying with lead arsenate, which is now part of the routine work on certain orange estates.

NEVIS. Not observed.

MISCELLANEOUS INSECTS.

ST. LUCIA. Grasshoppers particularly troublesome upon young growths of limes and oranges, especially on the latter. Insects 2 inches long and grass green found after sunset and before sunrise.

GRENADA. The bark of young twigs on lime trees amongst cacao injured by an undiscovered insect on one estate in a wet district.

NEVIS. None observed.

VIRGIN ISLANDS. Diaprepes and Lachnopus. Both these beetles have been numerous attacking growing parts of such plants as limes, citrus plants, Bay plants and, to small extent, cotton.

SWEET POTATOES.

SCARABEE (*Cryptorhynchus batatae*).

ANTIGUA. Reported from several localities. No serious damage done.

ST. KITTS. This pest occurs in lands to the north which are constantly planted in sweet potatoes.

NEVIS. Found in a few fields but not occurring to any great extent.

VIRGIN ISLANDS. None recorded.

CATERPILLARS (*Protoparce cingulata*, and others).

ST. LUCIA. General.

MONTSERRAT. Mild attacks of the caterpillar *Sylepta helcitalis*.

ANTIGUA. Fairly common in some fields but no serious damage done.

ST. KITTS. There was one attack of this insect at Pond estate, which was very severe during July.

NEVIS. None observed.

VIRGIN ISLANDS. Of local occurrence.

RED SPIDER (*Tetranychus telarius*).

ST. LUCIA. General in dry districts. Not seen in humid valleys.
ANTIGUA. Not noticed during the year.

MISCELLANEOUS INSECTS.

GRENADA. Slugs (*V. occidentalis*) have been very destructive to potatoes at Morne Rouge and Carriacou. This slug is known in St. Lucia as Leather Jacket.

DOMINICA. The palute (*Veronicella occidentalis*) often eats ferociously of the leaves of the sweet potatoes. The keeping of ducks is considered one of the best means of controlling this pest.

MONTSERRAT. There are general complaints about the destruction of newly planted sweet potato cuttings by the slug Veronicella.

VIRGIN ISLANDS. *Strategus titanus* (?)

GROUND NUTS.

GREEN BUG.

ST. VINCENT. Generally present, locally severe.

MEALY-BUG.

ST. LUCIA. Common.

ANTIGUA. Found in experiment plots.

LEAF-EATING CATERPILLARS.

ST. VINCENT. A Geometrid, not identified, at Ratho Mill. Woolly pyrol caterpillar.

MONTSERRAT. General attacks of the woolly pyrol moth; and if not controlled it is capable of severe damage. The season of feeding seems to be quite a long one, and it was controlled in Grove Station by the use of lead arsenate. In one field infested with the caterpillar, crapauds were noticed to be numerous.

ANTIGUA. Found in experiment plots.

MISCELLANEOUS INSECTS.

MONTSERRAT. One or two other caterpillars attack the growing plants but these have not been identified.

ST. KITTS. Plants of the ground nut were found at the Experiment Station attacked by the grub of *Exophthlamus esuriens*.

COCO-NUTS.

WHITE FLY (*Aleyrodicus cocois*).

GRENADA. Generally distributed.

ST. VINCENT. Generally distributed. (Leeward district.)

ST. LUCIA. Common in every grove in young stage. Not observed in established palms.

DOMINICA. The attacks reported last year from St. Joseph, Layou, and La Haut remain confined to this district.

SCALE INSECTS (*Aspidiotus destructor*, and others).

GRENADA. Generally distributed.

ST. VINCENT. Generally distributed.

ST. LUCIA. Generally distributed.

DOMINICA. Same as above. Both are commonly met with on coco-nuts throughout the island, but are of no serious consequence apart from the attack in the districts named.

ANTIGUA. Less common than in previous years.

NEVIS. *Aspidiotus destructor* observed in plantations and on coco-nut trees about the island.
Vinsonia stellifera observed in many places but not doing much damage.

VIRGIN ISLANDS. Of local occurrence, sometimes severe.

WEEVIL (*Rhyncophorus palmarum*).

ST. LUCIA. One case observed and treated.

MISCELLANEOUS INSECTS.

ST. VINCENT. A bag worm at Tourama. No damage.

INDIAN CORN.

CORN EAR WORM (*H. obsoleta*).

GRENADA. Generally distributed.

ST. VINCENT. Generally present, locally severe.

ST. LUCIA. Corn ear worm very troublesome in corn cultivation.

MONTSERRAT. Generally present throughout the year. (*L. frugiperda*).

ANTIGUA. Invariably present. (*H. obsoleta*).

ST. KITTS. The corn ear worm has been very prevalent during the past year.

NEVIS. *Heliothis armiger*. Observed in every field, and at times causing much loss.

VIRGIN ISLANDS. *Heliothis armiger*. Attacks recorded in peasants' corn.

HARD BACK GRUBS.

ST. LUCIA. Plentiful but no damage noticed.

ANTIGUA. The grubs of *Lachnosterna* sp. have caused considerable loss in connexion with maize grown in certain districts of the island.

ST. KITTS. Grubs of *Lachnosterna patruelis* were found in one instance attacking the roots.

NEVIS. Not observed.

MISCELLANEOUS INSECTS.

GRENADA. A caterpillar (probably Heliothis) destroyed much of the Carriacou crop.

ST. VINCENT. *Diatraea saccharalis* generally present, locally severe. Aphis generally distributed. Geometrid caterpillar attacks the silks.

The corn ear worm made its appearance in St. Vincent in June. In September it was very abundant at the Experiment Station, where 2,290 egg clusters were collected from the corn plants on ½-acre in twelve days. During Juneand July a serious attack of this insect was experienced at Bequia, where many other plants besides Indian corn were attacked.

ANTIGUA. Hard back grubs attacked corn roots in March and again in December, where they were very common and caused a considerable amount of damage.

ONIONS.

CATERPILLARS.

MONTSERRAT. The black caterpillar of *Prodenia* sp. troublesome in a few localities.

ANTIGUA. Common in all fields.

NEVIS. Observed attacking young onions in the nursery and also larger plants in the fields. Not so abundant this season.

THRIPS (*Thrips tabaci*).

MONTSERRAT. One severe attack noticed at windward in February 1915.

ANTIGUA. Fairly common in fields when crop ripening. Little or no damage done.

MISCELLANEOUS INSECTS.

VIRGIN ISLANDS. Two varieties of worms, probably the cutworm, (*Prodenia commelinae*,) sent to Head Office for identification.

Onions were attacked by thrips in Antigua during January and in Montserrat during February. Hard back grubs caused some damage to this crop in Antigua in December.

Ants and mole crickets were troublesome in onion seed beds in St. Vincent in November,

Yams.

SCALE INSECT (*Aspidiotus bartii*).

ANTIGUA. Common throughout the island. Done little damage.
ST. KITTS. Stored yams are usually attacked by this scale.

Green Dressings.

LEAF-EATING CATERPILLARS.

ST. VINCENT. Lima bean worm, attacked Rounceval peas, Lima beans, Bengal beans, etc.

ST. LUCIA. Slight attacks at certain seasons.

MONTSERRAT. A moderately severe attack by caterpillars of Bengal beans and allied plants in June, but not resulting in severe damage. No cases recorded of fields being destroyed by caterpillars.

ANTIGUA. Common in certain crops.

ST KITTS. Leaf-eating caterpillars have attacked crops of Bengal and other leguminous plants planted as a green dressing.

NEVIS. *Thermesia gemmatalis* observed attacking Lima beans in plot at Experiment Station.

MISCELLANEOUS INSECTS.

GRENADA. Undiscovered insect damaged the foliage of horse beans at Morne Rouge.

ST. VINCENT. Cryptorhynchus borer on Lima beans. Lima bean blotch miner.

Eudamus proteus attacked Lima beans.

ST. LUCIA. Red spider. Severe attacks in dry season.

MONTSERRAT. A tiny boring caterpillar attacks the leaves of the Lima bean but not to cause much injury.

ST. KITTS. Rounceval and Lima beans planted in the Experiment Station have been attacked by a small worm boring into the stem.

NEVIS. A boring larva of a small moth was observed at the Experiment Station doing considerable amount of damage in a plot of Rouncevals. Specimens were forwarded to Head Office.

MISCELLANEOUS INSECTS AND PESTS NOT OTHERWISE PROVIDED FOR.

GRENADA. Slugs (known in St. Lucia as 'Leather Jackets') have been very destructive to yams, beans and potatoes at Carriacou and Morne Rouge.

ST. VINCENT. Mite attacks cassava leaves. Tobacco was attacked by green bug during October. Arrowroot worm (*Calpodes ethlius*).

ST. LUCIA. Stem maggot in mahogany shoots and white cedar trees.

DOMINICA. The plaintain weevil as in former years is generally present in the southern half of the island. It is not reported from the Lasoye district. In certain districts it makes plantain growing a difficulty. It is known to attack bananas, but not to anything like the same extent as the plantain.

NEVIS. At Belmont estate and on other high lands considerable damage has been done to provision crops by slugs.

VIRGIN ISLANDS. *Batocera rubra*, a large longicorn beetle, is now established in the Virgin Islands. It attacks mango, avocado pear, papaw, banana. hog plum, species of Ficus, and the Bois Flot (*Ochroma Lagopus*), see *Agricultural News*, Vol. XV, p. 74, Feb 26, 1916).

NATURAL ENEMIES OF INJURIOUS INSECTS.

PARASITIC AND PREDACEOUS.

ST. VINCENT. (1) Egg parasite of cassava hawk moth (unidentified).

(2) 2. „ „ „ *Eudamus proteus* „
(3) 1. „ „ „ *Calpodes ethlius* „
(4) 2. „ „ „ *Nezara viridula* „
(5) 3. „ Tachiid parasites of *Calpodes ethlius* „
(6) Predaceous thrips attacks eggs of cotton stainer *D. delauneyi*.
(7) Mite attacks *Dysdercus delauneyi*.
(8) *Prophanurus alectus* parasitizes eggs of *Diatraea saccharalis*.
(9) An orange-red hymenopteron reared from eggs of *Diatraea saccharalis*.

ST. LUCIA. The local Jack Spaniard (*Polistes crinitus*), and the one from St. Vincent (*Polistes annularis*) worked well.

NEVIS. The parasite of the cotton worm (*Chalcis* sp.) was observed in many fields during the latter part of the year. The fiery ground beetle was also observed in some cotton fields.

GENERAL REMARKS.

ST. LUCIA. The Agricultural Superintendent's time being so fully occupied with extra work in connexion with the new schemes for the development of the island, it has not been possible to give these observations the close and regular attention they require.

MONTSERRAT. Ample rainfall was obtained from April to the end of the year. Very high winds during part of the cotton-growing season.

ST. KITTS. In consequence of the fine weather experienced, the attack of insect and other pests have not been noticed to any extent.

NEVIS. The crops, on the whole, were not damaged badly by any pest save in case of cottton when the worms were not properly dealt with.

The slug (*Veronicella occidentalis*) occurs throughout the Lesser Antilles. An article in the *Agricultural News*, Vol. XV, p. 138, April 22, 1916, gave a general account of this pest.

MISCELLANEOUS INSECTS.

GRENADA. Acrobat ant attacking Cacao.

ST. VINCENT. Bagworm attacking coco-nuts at Tourama. No damage. *Diatraea saccharalis* attacking Indian corn. Aphis attacking Indian corn. Geometrid caterpillar attacks silks. Cryptorhynchus borer attacking cotton at Expt. Station. Thrips attacked bolls.

MONTSERRAT. Mealy-bug on cotton.

ST. KITTS. Crickets attacked cotton at Frigate Bay.

GRENADA. Undiscovered insect damaged the foliage of horse beans at Morne Rouge.

ST. VINCENT. Cryptorhynchus borer on Lima beans. Lima blotch miner *Endamus proteus* attacked Lima beans.

MONTSERRAT. A tiny boring caterpillar attacks the leaves of the Lima bean but not to cause injury.

ST. KITTS. Small worm boring into the stems of Rounceval and Lima beans at Expt. Station. A boring larva of a small moth was observed at Expt. Station doing consider able damage to Rouncevals. Specimen sent to Head Office.

ST. VINCENT. A Geometrid not identified attacking ground nuts at Ratho Mill. Woolly pyrol caterpillar attacking ground nuts.

ST, KITTS. Exophthalmus attacking ground nuts. Undiscovered insect injures bark of young lime trees amongst canes on one estate in a wet district.

VIRGIN ISLANDS. Exophthalmus attacking citrus. Two varieties of worms attacking onions (names unknown) sent to Head Office for identification. *Strategus titanus* attacking sweet potatoes.

FUNGOUS AND BACTERIAL DISEASES.

BY W. NOWELL, D.I.C.,

Mycologist on the Staff of the Imperial Department of Agriculture for the West Indies.

SUGAR-CANE.

ROOT DISEASE (*Marasmius sacchari*, Wakker, and allied species).

GRENADA. Local attacks, not severe.

ST. LUCIA. Common, no serious outbreak.

ANTIGUA. Less prevalent on crop grown during 1915 than usual. One or two fields in the drier part of the island were badly attacked.

ST KITTS. This disease can be found throughout the island but there has been little damage owing to the favourable weather. B. 208 is very susceptible.

NEVIS. More prevalent this year, and if preventive measures are not adopted it will soon take a strong hold in the island.

RIND FUNGUS (*Melanconium sacchari*, Massee).

ST. VINCENT. Reported from two estates.

ST. LUCIA. Common but not abundant.

ANTIGUA. Fairly common during early part of 1915 on over-ripe canes.

RED ROT (*Colletotrichum falcatum*, Went.).

Attracted no attention in any island.

PINE-APPLE DISEASE. (*Thielaviopsis paradoxa* Maub. et Griff.)

Attracted no particular attention in any island.

OTHER DISEASES OF SUGAR-CANE.

NEVIS. *Cephalosporium sacchari*, Butler, was observed on a few estates doing a fair amount of damage.

COTTON.

ANTHRACNOSE (*Colletotrichum gossypii*, Southw.).

ST. VINCENT. Of minor importance.

MONTSERRAT. A few bolls noticed to be attacked by what appeared to be this disease, but it certainly is not of much importance.

ANTIGUA. Not prevalent.

WEST INDIAN LEAF MILDEW.

MONTSERRAT. Not at all general in spite of wet season.

ANTIGUA. Prevalent during latter end of season.

ST. KITTS. This pest attacks cotton in damp districts but little damage has occurred from it during the year.

NEVIS. Very abundant at the beginning and towards the end of the year.

BACTERIAL BOLL DISEASE.

ST. VINCENT. General, and severe in places.

MONTSERRAT. Not very prevalent. In one windward situation said to be badly drained it was very common.

ANTIGUA. Not common.

ST. KITTS. On account of the heavy rains many of the bolls turned black from this disease.

NEVIS. Very abundant during the wet months.

VIRGIN ISLANDS. Occurred generally.

ANGULAR LEAF SPOT.

ST. VINCENT. General, and severe in places.

MONTSERRAT. Fairly general and more of it than usual.

ST. KITTS. Prevalent but does not seem to do much damage.

BLACK ARM.

ST. VINCENT. General, and severe in places.

MONTSERRAT. Fairly common.

OTHER BOLL DISEASES.

ST. VINCENT. Internal boll disease caused heavy losses in some fields late in the season.

MONTSERRAT. Soft rot common as usual in damp localities.

ST. KITTS. Owing to rains there was much boll dropping.

VIRGIN ISLANDS. The internal boll disease caused some losses.

OTHER DISEASES OF COTTON.

ST. KITTS. There has been no recurrence this year of the loggerhead and curly-leaf diseases.

NEVIS. A gale followed by hot and dry weather did considerable damage to the plants in August. During the wet months a large number of bolls became hard and did not open. Called 'chilled bolls'. Attributed to the weather conditions which also led to 'black boll' and shedding.

VIRGIN ISLANDS. On the north side of Tortola great losses occurred from boll dropping early in the year.

CACAO.

ROOT DISEASE (*Rosellinia Pepo*, Pat.).

GRENADA. *Rosellinia Pepo*, generally distributed in wet districts; *R. bunodes* on Hibiscus near cacao.

ST. LUCIA. Common, but well in hand.

DOMINICA. It is quite a common occurrence to see patches of cacao trees dying from this cause. When neglected, as in one instance which came under observation, it is capable of assuming alarming dimensions and causing the death of several hundred trees. Should be treated vigorously.

CANKER (*Phytophthora Faberi*, Maubl.).

ST. LUCIA. Common; requires more attention.

DOMINICA. Generally distributed and is the cause of the death of many trees annually. The varieties Calabacillo and Amelonado are remarkably resistent when compared with the Criollo.

BLACK ROT OF PODS (*Phytophthora Faberi*).

ST. LUCIA. Common; requires more attention.

DOMINICA. Chiefly found on trees suffering from canker.

BROWN ROT OF PODS (*Lasiodiplodia Theobromae*, Griff. et Maubl.).

ST. LUCIA. No serious amount reported, but generally present.

DOMINICA. No severe outbreak recorded. Always present in cacao pickings. Careless disposal of cacao husks accounts to a large extent for its continued presence.

DIE-BACK AND STEM DISEASE (*Lasiodiplodia Theobromae*).

GRENADA. Causes damage in groups of trees here and there.

ST. LUCIA. Common; no serious infestations noted.

DOMINICA. Cacao trees may often be seen dying back, largely as a result of exposure.

PINK DISEASE (*Corticium salmonicolor*, B. et Br.).

Not noted. Occurs to a small extent in wet situations.

THREAD BLIGHTS.

Not noted.

HORSE-HAIR BLIGHT (*Marasmius sarmentosus*, Berk.).

Not noted. Occurs to a small extent in wet situations.

OTHER DISEASES OF CACAO, OR GENERAL REMARKS.

ST. KITTS. There is only one small cultivation of cacao, at Molineux estate, and with the exception of the number of young pods turning black, it seems fairly healthy.

LIMES AND OTHER CITRUS TREES.

BLACK ROOT DISEASE (*Rosellinia* spp.).

ST. LUCIA. Not known to occur in lime cultivations.

DOMINICA. A large amount of information regarding this disease has been obtained and published. It is now a matter for the planters concerned to see that the disease is controlled. Attacked trees are commonly seen in districts recently cleared from forest. No case is on record in Dominica where the sour orange stock has been attacked, and the local Department and several planters are experimenting with limes budded on sour orange stocks.

RED ROOT DISEASE (*Sphaerostilbe* sp.).

ST. LUCIA. Not known to occur.

DOMINICA. The disease on the coast is mainly confined to one district, but it is found on several estates in the interior. It is steadily gaining ground and, in spite of the efforts of the local officers of the Department to impress upon the planters concerned the importance of dealing with the matter, in most cases no thorough treatment has been attempted. Dead trees and stumps are often left unattended to for months. Under the circumstances the spread of the disease is to be expected. This disease was found on two grape fruit trees budded on sour orange stocks.

UNIDENTIFIED ROOT OR COLLAR DISEASES.

GRENADA. Fusarium disease suspected on limes in southern part of the island. The disease is associated with lack of drainage.

ST. LUCIA. So far the plantations remain free from fungoid root diseases.

PINK DISEASE (*Corticium salmonicolor*, B. et Br.).

DOMINICA. The pink disease of lime branches was observed on two or three occasions in wet situations.

OTHER DISEASES OF LIMES.

ST. LUCIA. The fungus causing damping-off of seedlings was very destructive throughout the year, killing off the plants as soon as they appeared above the soil. The continuous rains made the fungicides used ineffective.

SWEET POTATOES.

ROOT DISEASE (*Marasmius sacchari*, Wakker).

ANTIGUA. Apparently not as common as in previous years.

WHITE RUST (*Albugo* (Cystopus.) sp.).

Attracted no particular attention in any island.

GENERAL REMARKS.

ST. KITTS. Sweet potatoes are cultivated only in one district in the island to any great extent, the estates not planting them as a crop. Beyond attacks of Scarabee they are healthy.

COCO-NUTS.

BUD ROT.

NEVIS. Not known to occur in the island.

VIRGIN ISLANDS. Not known.

No recorded instances during the year in any island.

ROOT DISEASE

GRENADA. Some trees seen with dwindling tops were suspected of root disease.

LEAF DISEASES (*Pestalozzia palmarum*, Cke.).

DOMINICA. There have been no reports of outbreaks during 1915.

GENERAL REMARKS.

ST. KITTS. Coco-nuts are not grown on a large scale in St. Kitts; the trees, on the whole, are very healthy.

NEVIS. The plantations, on the whole, are perfectly healthy.

INDIAN CORN.

RUSTS (*Puccinia* spp.).

ST. VINCENT. Brown rust (*P. Maydis*, Ber.) general but not severe.

MONTSERRAT. Brown rust occurs but has not been noticed to be very prevalent.

ANTIGUA. Common in most fields (species not stated).

SMUT (*Ustilago Zeae*, (Beck.) Ung.).

MONTSERRAT. Occurs sporadically.

ANTIGUA. More common than in previous years.

ROOT DISEASE.

ST. VINCENT. An undetermined root disease has caused some loss.

ANTIGUA. It is difficult to say to what extent root disease occurs.

IMPHEE AND GUINEA CORN.

RUST (*Puccinia purpurea*, Cke.).

NEVIS. Rust occurs throughout the island, but as the attack is generally when the ears are maturing, it is not considered serious.

SMUT (*Sphacelotheca sorghi*, (Lk.) Clint.)

ST. VINCENT. Occurs but not to a serious extent.

GROUND NUTS.

ROOT DISEASE (*Sclerotium* sp.).

MONTSERRAT. Observed at Grove Experiment Station.

LEAF RUST (*Uredo arachidis*, Lagl.).

ST. VINCENT. General and locally severe.

ST. LUCIA. Slight attacks.

MONTSERRAT. Interesting results were obtained in the control of rust by means of Bordeaux mixture. It was noticed, however, that not all areas in ground nuts were attacked, and certain areas seemed to be quite free from rust.

ANTIGUA. Prevalent on foliage of plants grown at the Experiment Station.

LEAF SPOT (*Cercospora personata*, Ellis).

MONTSERRAT. One area which did not show rust was badly spotted and it may have been this disease, though specimens were not sent for examination.

GENERAL REMARKS.

ST. KITTS. Ground nuts are grown to some extent in the upper lands of St. Kitts but no diseases of any consequence have been reported.

ONIONS.

BACTERIAL ROT.

MONTSERRAT. Very prevalent on the crop reaped at Harris Station in February 1915. Experience would seem to show that this disease is likely to occur on badly drained land, the soil at Harris being one of the wettest in the island on account of the contour of the surrounding hills.

ANTIGUA. Common after reaping.

General Remarks.

ST. KITTS. Onions are only grown on a small scale in St. Kitts.

MONTSERRAT and ANTIGUA. Considerable trouble was experienced with the damping-off of seedlings.

Yams.

TUBER DISEASES.

ANTIGUA. Not observed during the year.

WILT DISEASES.

ANTIGUA. Reported from several localities. Possibly did a considerable amount of damage.

Fungi Parasitic on Insects.

ON SCALE INSECTS.

GRENADA. Shield scale fungus, *Cephalosporium lecanii*, well distributed and plentiful, Black fungus. *Myriangium duriaei*, sparsely distributed. White-headed fungus, *Ophionectria coccicola*, very well distributed and plentiful. Red-headed fungus, *Sphaerostilbe coccophila*, well distributed but not plentiful.

ST. LUCIA and DOMINICA. The wet year 1915 was highly favourable to all fungus parasites on scale insects.

ANTIGUA. Shield scale fungus, black fungus, and red-headed fungus probably more common than in previous years.

NEVIS. The shield scale fungus was observed on green scale, *Lecanium viride*, in damp localities.

ON OTHER INSECTS.

ST. VINCENT. A fungus on the cacao thrips was noticed which at some periods seemed to be very effective in reducing the numbers of that insect. A new species of Cordyceps was found on a Sphenophorus boring in crotons.

Phanerogamic Parasites.

LOVE VINE (*Cuscuta americana*, L., and sometimes *Cassytha filiformis*, L.).

ST. LUCIA. A pest throughout the island.

DOMINICA. Not reported from any new localities. No serious efforts have been made to stamp it out.

ANTIGUA. Increased during the year in one locality.

ST. KITTS. This pest has increased latterly, especially along the ravines near the road sides, but it is chiefly confined to hedges and wayside plants, no valuable crops being attacked.

NEVIS. Very abundant in one neighbourhood and has got into a lime cultivation.

VIRGIN ISLANDS. A very troublesome pest which seems to be on the increase.

MISTLETOE. (*Dendropemon* sp., *Phoradendron* sp.).

ST. LUCIA. Very common throughout the island.

DOMINICA. Continues to injure many acres of cultivation in Dominica through neglect to cut out affected branches.

VIRGIN ISLANDS. A troublesome pest.

Remarks on any Other Plant Diseases.

ST. VINCENT. Root disease attacked beans in wet seasons and killed them. The mosaic disease of tobacco, and a bacterial disease of cassava were noticed.

GRENADA. A disease of nutmegs resembling a bleeding canker of the stem has been observed to be locally severe in a wet district. Specimens have not yet been procured.

A leaf spot disease of nutmegs has been reported from a wet district. Specimens examined by the Mycologist bore a species of Phyllosticta.

MONTSERRAT. The expermental plot of pine-apples at Grove Station suffered from a wilt disease. The first indications were a reddening of the foliage and ultimately the drying of the leaves. The roots of diseased plants were found to be in a decayed condition.

SUMMARY OF DISTRIBUTION.

The following table is intended to show the status and distribution of the insects, fungi, and vegetable parasites attacking the principal crops. It has been drawn up from the information available at the Head Office of the Department, and has not been re-submitted to the officers in the various islands. While not claiming to be exact, it may be taken as affording a fair summary of the position during the year in question.

EXPLANATION OF SIGNS USED.

g = generally distributed.

G = generally distributed, severe.

l = local.

L = locally severe.

g L = Generally distributed, locally severe.

r = recorded present.

? = doubtful occurrence.

— = not known to occur in the island.

o = no record during the year.

A blank against the pests or diseases of any particular crop means that the crop is not grown at all or is not important in that island.

INSECT PESTS.

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
Cacao.									
Thrips	g L	g L	r	g L			o	–	
Beetle	L	–	?				o	–	
Scale Insects and Mealy-bugs ...	r	g	o				o	–	
Termites	l								
Root Grubs				L			–		
Acrobat Ant	l								
Coco-nuts.									
Weevil	o	o	r			o	–		
White Fly	g	g	g	g L		o	o		
Scale Insects	g	g	g	g L		g	o	g	L
Bag Worm		r							
Corn (Indian).									
Corn Ear Worm and Boll Worm	g	g L	g		g	g L	G	g	L
Hard Back Grubs	o	–	g			L	r		
Moth Borer		g L							
Aphis		g							
Geometrid Caterpillar		g							
Cotton.									
Cotton Worm	o		G		G	g L	g L	G	L
Boll Worm and Corn Ear Worm	o	o			r	g	o		
Cotton Stainers	o	g L	g		g	g	r	g	L
Scale Insects	o	L	o		r	r	o	r	
Flower-bud Maggot	o	–				o	–		?
Leaf-blister Mite	o	g	g		r	g	g	G	G
Bronze Beetle		g L							
Lachnopus								r	
Aphis						r		r	
Cockroaches							L		
Cryptorhynchus Borer		r							
Thrips		g							
Mealy-bug					r				
Crickets							r		
Green Dressings.									
Leaf-eating Caterpillars ...	o	g	g		g	g L	g	r	
Cryptorhynchus Borer		g							
Blotch Miner		G							
Bean Leaf Roller		g							
Stem Borer							L		
Red Spider			g						

INSECT PESTS.—(*Continued.*)

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
Ground Nuts.									
Green Bug	o	g L	?				–	–	
Mealy-bug	o	–	g			r	–	–	
Caterpillars	o	L	o		r	r	o	-	
Root Grubs						l			
Limes and Other Citrus Trees.									
Scale Insects	g	G	g	g L	g	g		g	L
Bark Borer	?	–	?	l		?			
Twig Borer	o	–	?	r					
Orange Moth	o	–	–	l					
Root Borer Grubs			–	r	g	(?)	L		?
Lachnopus									
Grasshoppers				g					r
Onions.									
Caterpillars	o	–			l	g	o	r	g
Thrips	o	–			r	g	o		
Sugar-cane.									
Moth Borer	o	gL	g		g	g	g	g	G
Weevil Borer	o	o	g			g	o	l	
Root Borers—Diaprepes ...	o	o	g				gL		
Exophthalmus ...	o	o	o?			l	L	g	?
Cane Fly	o	–	o				o		
Termites	o	–	o			r	l		
Hard Back Grubs (Lachnosterna)	o	–				L	g	g	
Mealy-bug ...		r				g			
Grasshoppers							gL		
Sweet Potatoes.									
Caterpillars	o	o	g		r	r	L		l
Scarabee	o	o.				r	l	r	
Red Spider	o	o	g						
Slugs	G			g	g				
Rhinoceros Beetle									?
Yams.									
Scale Insects	o	o				g	g	–	

DISEASES.

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
CACAO.									
Root Disease	g L	l	g	g L					
Canker	g g	o	g g	g g					
Black Pod Rot	g g	g	g g	g g					
Brown Pod Rot	g g	o	g g	g g					
Die-back and Stem Disease ...	l	g	g	g L					
Pink Disease	r	–	o	o					
Thread Blight	r l	–	–	o					
Horse-hair Blight	o	–	–	o					
COCO-NUTS.									
Root Disease	r	o	–	–	–	?	–	–	–
Bud Rot	o	o	–	–	–	o	–	–	–
Leaf Disease	o	o	o	o	o	o	o	o	o
CORN (INDIAN).									
Rust	o	g	o		g	g	o	o	o
Smut	o	–	–		l	g	o	o	o
Root Disease	–	L	–		–	?	–	–	–
COTTON.									
Anthracnose	o	g			l	o	o	o	o
West Indian Leaf Mildew ..	o	g			g	g	l	g	o
Bacterial Boll Disease	o	g L			g L	l	g	g	g
Angular Leaf Spot	o	g L			g	l	g	o	o
Black Arm	o	g L			g	l	o	o	o
Internal Boll Disease	o	g L			l	o	o	o	r
Loggerhead Disease	–	–			–	–	o	o	–
Curly-leaf Disease	–	–			o	o	o	o	–
GROUND NUTS.									
Root Disease	o	o	–		r	o	o	o	
Leaf Rust	o	g L	l		l	L	o	o	
Leaf Spot	?	o	o		?	o	o	o	
GUINEA CORN AND IMPHEE.									
Rusts	o	o					o	g	
Smut	o	g					o	o	

DISEASES.—(*Concluded.*)

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
LIMES AND OTHER CITRUS TREES.									
Black Root Disease	–	–	–	L	–	–			
Red Root Disease		–	–	L	–	–			
Pink Disease	–	–	–	l	–	–			
ONIONS									
Bacterial Rot					L	g			
SUGAR-CANE.									
Root Disease	l	o	g		o	g L	g	g	o
Rind Fungus	o	L	g		o	g	o	o	o
Red Rot	o	o	o		o	o	o	o	o
Pine-apple Disease	o	o	o		o	o	o	o	o
SWEET POTATOES.									
Root Disease	o	o	–		o	r	o	o	o
White Rust	o	o	o		o	o	o	o	o
YAMS.									
Tuber Disease	–	–	–			o	–	–	
Wilt Disease	–	–	–			L	–	–	
PHANEROGAMIC PARASITES.									
Love Vine	g	g	g	L		l	g	L	g L
Mistletoe	l	o	g	g L		–	–	–	g

Collection of Exopthalmus Weevils in Grove Station, Montserrat.

1914.

March	...	...		2,025
April	...	...		541
May	...	...		96
June	...	...		1,113
July	...	...		64
August	...	...		53
September		...		20
October	3	...	49	
,,	10	...	39	
,,	17	...	23	
,,	23	...	18	
,,	31	...	92	221
November	6	...	85	
,,	13	...	102	
,,	18	...	37	
,,	20	...	63	
,,	27	...	46	333
December	1	...	56	
,,	11	...	63	119
				4,585

1915.

January	2	...	12	
,,	9	...	20	
,,	20	...	30	62
February	11	...	34	
,,	18	...	12	
,,	22	...	10	56
March	6	...	28	
,,	19	...	32	60

1915.—(*Continued.*)

April	17	...	29	
,,	20	...	92	
,,	30	...	73	194
May	3	...	34	
,,	8	...	99	
,,	11	...	23	
,,	15	...	38	
,,	19	...	17	
,,	22	...	22	
,,	29	...	40	273
June	6	...	63	
,,	12	...	46	
,,	19	...	44	
,,	26	..	85	238
July	17	...	23	
,,	24	...	18	41
August	14	...	24	
,,	26	...	12	36
Sept'ber	10	...	12	
,,	22	...	26	38
October	2	...	12	
,,	13	...	13	
,,	23	...	21	64
				1,014

ROSELLINIA ROOT DISEASES IN THE LESSER ANTILLES.

BY W. NOWELL, D.I.C.,

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The genus *Rosellinia*, Ces. et de Not. consists, according to Lindau in *Die natürlichen Pflanzenfamilien*, of more than 170 species. It is regarded as certain, however, that so far as the species already described are concerned, this number would be very considerably reduced if a general survey of the genus were made and the material on which the descriptions were based compared.

The fructifications of most of the species are found on dead wood and bark, and they are in the main assumed to be saprophytes. Since the perithecia of those species known to be capable of parasitism are also produced as a rule only on dead material, their situation affords no real evidence as to the mode of life of the mycelium in its earlier stages. Any species of Rosellinia occurring in the neighbourhood of cultivated trees should therefore be viewed with suspicion.

The number of species of Roseliinia known to the writer to occur in the West Indies is five. Two of these, *R. bunodes*, (B. et Br.) Sacc., and *R. Pepo*, Pat., are known to be the cause of destructive root diseases of cultivated and other plants, mainly trees or shrubs; the third, a species as yet unidentified, is suspected of being the cause of a root disease of cacao; the fourth, only found as yet on a dead tree is, if the tentative identification as *R. bothrina*, B. et. Br., is correct, known as causing a destructive root disease of tea and other plants in Ceylon; the fifth, also found on a dead tree, is reported to be apparently *R. subiculata*, (Schw.) Sacc., a species as to which I have no information.

With regard to the name *Rosellinia hartii*, Mass, given at Kew to a fungus found in Trinidad on a fallen cacao branch, J. B. Rorer, (1911) Mycologist to the Board of Agriculture in that island, remarks :—

In reply to a letter from the writer, the Director of the Royal Gardens stated that the name *Rosellinia hartii* should not be used in connexion with this fungus as a mistake had been made in the determination.'

I. HISTORICAL.

EXTRA-WEST-INDIAN RECORDS OF ROSELLINIA DISEASES.

The literature at my disposal does not suffice for anything approaching a complete review of the information published on Rosellinia diseases in other parts of the world. Any attempt at such a review is moreover rendered difficult by the absence from many reports concerning root diseases of trees of adequate information as to the causative fungus. Delacroix (1911) quotes several such inadequate descriptions froms various countries, some

of which almost certainly and others possibly refer to Rosellinia disease. Affections of similar type would seem to occur or to have occurred in most tropical countries opened up to agriculture. That other fungi than Rosellinia may however be the cause of such diseases in the Tropics has been clearly shown by Petch and others in Ceylon and Malaya, and is illustrated by the occurrence, parallel with Rosellinia disease, of the red root disease of lime trees in Dominica.

The first disease attributable to Rosellinia to attract attention from investigators seems to have been the root rot (*Pourridie*, *Weinstockfaule*, *Mal Nero*) of the vine in Europe, concerning which an important literature, not at present accessible to me, exists. Under the name of *Dematophora necatrix*, R. Hartig, the causative fungus was known by its mycelial characters, as is usually the case with Rosellinias, long before the perfect form was recognized, and to Hartig only the conidial (*Graphium*) fructification was known. According to the account given by Prillieux (n.d.) the perithecia were first discovered and described by Viala. As was pointed out by Berlese and Prillieux they are without doubt those of a Rosellinia, and while some writers may have included under the name Dematophora mycelial forms not so connected, there can be little doubt from a comparison of Hartig's figures with the characters of other described species of Rosellinia that he was, in the main, working with the same fungus.

The disease is a very serious one in the vine-growing countries of Europe and is recorded from the U. S A. It is said to occur only in wet soils. Many trees are recorded as being attacked by it, as also are a number of herbaceous plants.

In 1880 R. Hartig (Prillieux, n.d.) described *Rosellinia quercina* as the cause of a disease attacking the roots of young oaks in nursery beds in Germany. The fungus develops only under hot and humid conditions.

In 1893 Prillieux and Delacroix (Prillieux, n.d.) gave an account of their studies, upon the mulberry, of a root disease which also attacks hawthorn, birch and other trees, and is caused by *Rosellinia aquila*, (Fr.) de Not. It attacks the collar and superficial roots in a manner very similar to that of the West Indian species afterwards to be described, and produces a conidial form (Sporotrichum or Trichosporium), followed by perithecia, on the surface of the dead wood. The branches of the tree dry up and die one after another in most of the observed cases, and in wet soils the tree dies in about three to four years. In other cases the tree dies much more suddenly, the drying up of the leaves and branches being completed in seven or eight days. Such cases occur more especially in certain alluvial soils. Under dryer conditions the disease develops more slowly. Similar differences in the development of the attack of the fungus will be described in connexion with Rosellinia disease of lime trees in Dominica.

R. A. Wight (1889) gave an account of a root disease occurring in New Zealand which attacks the roots of all the common orchard trees, the whitethorn, *Abies*, ferns, introduced vegetables, and several native trees and plants. Resinous pines

and roses are the only plants known to successfully resist its attacks. It spreads through an orchard, killing the herbaceous plants as it goes, until it reaches a tree. It attacks the bark of the stem just under the surface of the soil and proceeds along the roots. It is erratic in its progress, and may take a tree or a row here and there, or kill out an entire orchard in a few years.

It is most plentiful on the skirts of the primeval forests and on fern lands adjoining, where no cultivation has ever been resorted to. On dry lands where native stumps remain it is very prevalent. It is confined to dry soils.

G. Massee (1896) received collections of material from New Zealand containing a fungus which he regarded as responsible for the disease above described. From the mycelial characters it was referred to *Dematophora necatrix*, but later similar material bearing perithecia came to hand and the fungus was described as a new species, *Rosellinia radiciperda*, Mass. In an experiment at Kew it was found that infested material placed in a box of soil infected an apple root and seedling beeches.

Later Massee (1901) described *Rosellinia echinata*, sent to Kew from the Botanic Gardens, Singapore, by H. N. Ridley, Director, who wrote :—

Some months ago all the shrubs in a jungly bit of the garden, at the foot of a large *Ficus dubia*, began to die, turning black, and the long roots of the Ficus did the same. At first I thought some weedkiller had been carelessly thrown into the wood, but the thing increased, every plant withered and died, looking as if acid or boiling water had been thrown upon it. All kinds of dicotyledonous shrubs and herbs, rattans, *Dracaenas*, and even some *Dieffenbachias* turned black and rotted. At last the thing developed on the fig roots and on the collar and roots of all the trees and shru s around, and appears to be a deadly fungus.

Watt and Mann (1903), who give references to Indian papers not seen by me, describe a Rosellinia root disease of tea noted almost from the beginning of tea planting in India. They state as a well-known fact that certain shade trees within a garden, if killed, or felled, cause the death of a number of tea bushes around their stumps. The trees with the worst reputation in this respect belong to the genera *Machilus*, *Melia*, *Erythrina* and *Bombax*, all soft-wooded; *Mesua* and *Grevillea* are also attacked. The disease is general in forest land and is the most usual cause of the circles of vacancies so common in many gardens.

J. B. Carruthers (1903) described the constant losses from root disease in the hill-country tea gardens in Ceylon, attributing it in great part to a Rosellinia of which he occasionally found the perithecia. An attempt to infect a tea plant growing in a pot of sterilized soil by sowing the spores of the fungus failed, but he succeeded in getting a vigorous growth of the fungus by the same means on buried tea branches which had been previously sterilized.

T. Petch (1910 b) in a later account divides up the root diseases of tea in Ceylon amongst a number of fungi, of which he describes five. The *Rosellinia* appears to be the least common of these. Several species occur in Ceylon, but in all cases the fructifications found on tea have proved to be those of *R. bothrina*, B. et Br. This species also attacks *Panax*, *Strobilanthes*, *Grevillea*, and

camphor, but has been seen to leave cacao and *Hevea* unaffected in a diseased area. It has been found once on *Erythrina*. It occurs at all elevations in the hills, but has not been seen in the low country.

Petch minimises the function of stumps as centres of origin for the disease, being of opinion that it generally begins from spore-infection of an accumulation of dead leaves such as may occur against a stump or prostrate log. The mycelium travels through the top 2 or 3 inches of soil if it contains a sufficient amount of decaying vegetable matter, or on the surface under a layer of dead leaves. Under the favourable conditions supplied by a *Panax* hedge it will travel 3 or 4 yards in a few weeks. On reaching a tea bush it travels down the root for a distance of about a foot. The mycelial characters and the form and method of fruiting as described by Petch resemble very closely those of *R. Pepo* described below.

Rosellinia bunodes, (B. et Br.) Sacc., previously known in Ceylon as a saprophyte only, has recently been recorded by Petch (1915) as parasitic there on *Hibiscus*.

Reference is made from time to time to losses caused by root diseases, known in general terms as stump rot, on coffee and other cultivated trees in Southern India. The causative fungi include a destructive Rosellinia, which according to a brief reference by Petch is *R. bunodes*, and is parasitic on *Coffea*.

Massee (1895) records a disease 'closely allied to *Dematophora necatrix*' killing out *Piper nigrum* in Southern India (Mysore) over patches of the plantation up to 15 yards square, and fatal also to saplings and forest undergrowth occurring on the same site. E. G. Butler (1905) in reporting what is presumably the same disease from Mysore, gives the species of the fungus as *Rosellinia bunodes*, and says that it kills out in patches both the pepper vines and their living supports.

West Indies.

In reviewing the records of the occurrence of root diseases in the West Indies, although the authors of the earlier descriptions do not as a rule report any observations of the fructifications, one is on fairly safe ground in attributing the diseases described to Rosellinia. I am unable to agree with South (1912) in regarding the disease referred to by Barber, Howard, Earle, and Auchinleck, for which he adopts the name 'white root disease' as being distinct from the 'black root disease' described by him. Under the latter name he has included the characters both of the form of the disease due to *Rosellinia bunodes* and of that due to *R. Pepo*. To the latter form when separated the descriptions of the 'white root disease' conform reasonably well, and close investigation in Dominica, St. Lucia, and Grenada has failed to reveal any other disease to which the early descriptions could possibly refer. The description of the mycelium as white throughout might easily arise from a failure to connect the white fans, under the cortex with the very different dark mycelium on the exterior, which moreover is often only well developed when the fungus gets above the surface of the soil. The attribution of the cacao root disease to

a Basidiomycete by both Howard and Stockdale, based on the finding of clamp connexions in the hyphae, seems to indicate either that this character has less diagnostic value than they credited it with, or that the mycelium of some secondary fungus was present in the material examined.

The first account seen referring to the British West Indies is that of Barber (1893) from Dominica, which except as regards the surmise as to the fructification needs no correction to-day. He says:—

Perhaps the most serious disease affecting the cacao trees in Dominica is a curious one affecting the roots. A tree, in apparently good soil, and of considerable health and vigour, suddenly dries off from the root. The neighbouring trees are seen shortly to be similarly affected and frequently the patch of infected trees attains considerable dimensions. Liberian coffee trees particularly seem to dry up, and as it were 'petrify' with all their berries on them. Where several cultivations are mixed, the mysterious disease frequently selects one kind and works its way beneath the surface in search of its particular prey. In other cases again all the trees of the infected area seem liable to it.

A careful examination has led me to believe that this disease is caused by the mycelium of a fungus. In all cases I have succeeded in discovering a white fan-like network of hyphae between the bark and wood of the roots (i.e. in the cambium) and by this fan-like network the root-fungus may be known. The fructification is I believe a lateral growth of mushroom-like character which is usually seen on old trunks of dead trees a few feet from the ground. But it is the insidious mycelium which creeps from tree to tree beneath the surface that we have to fear, and one feels helpless against it.

The following plants were noted as liable to attack: mango, orange, bitter orange, lime, pois-doux (*Inga* sp.), coffee, cacao, breadfruit, eddoes, sugar-cane, *Cassia Fistula*, and cassava.

The author remarks that he noticed a similar disease called locally 'saltpetre', in the cacao and coffee cultivation in Jamaica.

Since the establishment of the Imperial Department of Agriculture in 1900, reports of the occurrence of Rosellinia disease have continued to come in from time to time from Dominica, St. Lucia and Grenada. Recently the existence of Rosellinia diseases in St. Vincent has been verified. The more interesting communications are summarized below.

DOMINICA.

1901. Joseph Jones, Curator of the Botanic Gardens, wrote:

An instance of the supposed effect of a dead avocado pear tree on the surrounding cacao was seen at this station. There is a belief in Dominica that when one of these trees is cut down in a cacao field the trees near die off in a mysterious manner. In the case in question one of the cacao trees near the avocado stump was evidently affected in some way and the root-systems of the two trees were consequently exposed and carefully examined. Both root systems were attacked by fungi but it was impossible to determine whether the disease had spread from the avocado pear tree to the cacao, or vice versa.

1905. Arabian coffee trees were reported dying in large numbers in a situation on which secondary forest had been felled five years previously. *Coffea stenophylla* seemed more resistent. Attributed by L. Lewton-Brain, then Mycologist to the Department, from specimens examined, to *Dematophora.*

1909. Three-year-old lime tree (planted out two years) growing near stump of mahaut cochon, killed by a fungus which from the description given was clearly *Rosellinia* sp.

1909. The Curator wrote :—

You are aware that on newly cleared forest land planted in limes, cacao, and coffee it is quite common for plants to die out in patches during the early years after planting. This is said to be due to a fungus which develops on the decaying roots of certain forest trees. The local treatment is to lime the infected land and replant after a period. With the decay of the forest roots the disease disappears.

1910. Several of the best looking lime trees were dying on land cleared from forest four years previously; trees planted three years. Rainfall 150 inches. Many roots were still sound after the trees were dead. One tree examined had only one diseased root, which led to a mahaut cochon stump. Clearly Rosellinia from the description.

1910. A similar report from another estate; lime trees 3-4 years old dying off.

ST. LUCIA.

1907. G. S. Hudson, Agricultural Instructor, reported that a root disease of cacao had lately been much in evidence, killing off the trees in patches generally circumscribed by the surface spread of the roots of such shade trees as bread fruit, bread-nut, and avocado pear, which had either been killed, or were dying from natural causes. The typical sign of the disease is a white web found between the bark and the wood of old diseased roots. In a letter written the same year he states that trees planted on a diseased spot after a long interval have died out when they were about ten years old.

1910. In consequence of a 'scare' paragraph in a local newspaper, J. C. Moore, Agricultural Superintendent, made an extensive tour of the estates in order to estimate the status of the disease on cacao. He reported that it had been known for several years in the island, and was generally distributed but not abundant.

1911 et seq. Reference is made to the disease in the Reports of the Agricultural Department of St. Lucia from 1911 on, and the results are given of certain experiments carried out in connexion with it. In 1912 F. W. South and A. J. Brooks wrote a report on the subject of the disease which was published in a circular for local distribution.

GRENADA.

1901. The first Grenada reference traced is contained in a report by A. Howard, Mycologist to the Imperial Department of Agriculture, published in the Grenada *Official Gazette*, dealing with the diseases of cacao seen in the course of a month's tour in that island in 1901. The author states that three patches of diseased trees were seen occurring in good well-drained soil and surrounded by healthy vigorous trees, and that the disease seemed to be identical with that described by Barber in Dominica. In recommending the usual treatment he mentions that this had already been successfully carried out by planters in

dealing with a disease of nutmeg trees probably due to the same fungus.

1910. On an estate in a forest locality a large number of cases of Rosellinia disease attacking Castilloa occurred. The fungus was afterwards stated by South, who examined the specimens, to be *R. bunodes*, which was identified from the same district in 1912, causing root disease of camphor plants in an experiment plot.

In the same year G. G. Auchinleck (1910), the local Superintendent of Agriculture, delivered a lecture on root diseases of cacao. He exhibited a photograph of which a copy is before me, of the fan like clusters of mycelium under the bark, and I have no hesitation in saying that this is Rosellinia, in all probability *R. Pepo*. He expressed the opinion that the disease was commoner in Grenada than was generally believed, and reported having recently found it in the upland cultivations of several parishes. It is most prevalent on the heavy clays of mountain lands. He gave as additional host plants observed in Grenada: coffee, nutmegs, breadfruit and bananas.

A type of cacao root disease occurring on some of the lowland estates, due to a third species as yet unidentified and apparently undescribed was recently found by the present writer (1915).

ST. VINCENT.

In St. Vincent a disease of arrowroot known as burning has been known for many years. Specimens were sent to Kew in 1891. South (1912) suggested the connexion of this disease with Rosellinia, and this has been confirmed by the present writer, the species being referred on the grounds of its mycelial characters to *R. bunodes*.

South (loc. cit.) reports the finding of a dying cacao tree with a mycelium similar to that of his black root disease, and, on the edge of a field of diseased arrowroot, of cacao seedlings with mycelium, conidiophores and perithecia very like those seen by him in Dominica, i e., of *R. bunodes*. This is the only instance of that species attacking cacao with which I am acquainted.

Recently the writer found numbers of dead and dying cacao trees in one locality which were heavily infested with the unidentified species mentioned as occurring in Grenada

JAMAICA.

Although it is clear that this or a closely similar disease occurs in Jamaica I have found few published records. Barber's reference has already been mentioned. Earle, (1903) in a report of a journey made in 1902, the object of which was the investigation of diseases of economic plants, refers to a serious root disease of logwood trees which affects trees in groups and spreads in constantly widening circles. A white mycelium is abundantly developed between the bark and the wood. Seemingly healthy trees near the border of infested areas had the roots on the side next to the dying trees attacked, while

those on the other side were perfectly healthy. The disease occurred under very various conditions of soil and drainage. It was stated by labourers that the roots of cassava rotted if it was planted on infested land.

In an editorial review of Stockdale's pamphlet on *Sanitation of Cacao Orchards*, the *Journal of the Jamaica Agricultural Society* (1909) says:—

We have always known that [avocado] pear trees among cocoa trees were inimical to the health of the cocoa. Whenever a pear tree dies—and in many districts, just those where cocoa is most grown too, where it is humid and soils are heavy, the life of the pear tree is short—its roots rot and are usually a mass of corruption, which may infect all the trees in the cultivation.

THE FRENCH ANTILLES.

The available literature respecting Rosellinia disease in Guadeloupe and Martinique mostly has reference to its occurrence on coffee. As early as 1842 Guerin-Meneville and Perrottet wrote concerning this plant in the Antilles (trans.):—

A disease attacks the coffee trees in some localities and is the cause of their death at the time when one expects it least. The disease, which develops in the ground, poisons, according to local opinion, all the coffee trees attacked by it. It is caused by a very small fungus, which spreads in a very short space of time, especially when the soil is rich in easily decomposed vegetable remains. Such material favours the growth of the fungus by maintaining a constant humidity at the foot of the tree and by hindering the circulation of the air in that region.

The authors recommend that the diseased trees be dug up and burnt, and the infested soil cleared of vegetation.

Delacroix (1900) under the name of *pourridie des racines* gives an account of a disease of Arabian coffee of which he had received numerous examples from Guadeloupe. No fructifications were present, but the mycelial characters closely resembled those of *Rosellinia necatrix*, and the author figures the familiar 'varicose' hyphae characteristic of *Rosellinia* spp. According to information supplied with the specimens the disease spreads to the coffee from the roots of pois-doux (*Inga* sp.) used as shelter. Annatto (*Bixa orellana*) is also susceptible. The disease upon the coffee is complicated by the presence of eelworms.

Patouillard (1910) examined similar material sent from Guadeloupe, and reported that the general aspect of the mycelium suggested *Rosellinia* or *Dematophora*.

Bordaz, in an article published in a Martinique newspaper in 1914, referred to a very destructive root disease on cacao and other trees in that island In acknowledging recently a copy of Pamphlet 79 of this Department, he writes: 'the description of the disease of limes and cacao [Rosellinia] puts it beyond all question that here, at least on cacao, we suffer from the same affection.'

PORTO RICO.

G. L. Fawcett (1915) discussing coffee diseases in Porto Rico gives an account of two types, white and black, of a root disease found in many plantations. Of these he reports that the black type, which is perhaps the more common and has been more thoroughly studied, is due to ***Rosellinia*** **sp., apparently** ***R. bunodes*****.**

The account given corresponds exactly, in the description of the fungus and of the conditions of occurrence of the disease, to the situation on lime estates in forest clearings in Dominica. It may be noted, however, that while in Porto Rico Fawcett has found perithecia only twice, in Dominica the present writer has found those of *R. bunodes* very frequently, often long before the trees were killed. In the latter island the 'white' type of the disease has been shown to be due to *Rosellinia Pepo*.

INVESTIGATION BY THE MYCOLOGISTS OF THE IMPERIAL DEPARTMENT OF AGRICULTURE.

From time to time notes and articles on the subject of Rosellinia disease in Dominica, Grenada, and St. Lucia, written by the mycologist for the time being of the Imperial Department of Agriculture, have appeared in the Departmental publications. It should be noted that these officers have been stationed in Barbados, and dependent for their information on shipped material and on observations made during short and infrequent visits.

A. Howard (1901-2), in addition to the Grenada reference already given, published a short note repeating the same information and referring briefly to material of identical appearance received from Dominica.

F. A. Stockdale (1905-9) briefly described the disease as it affects cacao in Grenada, Dominica and St. Lucia. He regarded as an established fact the spread of the fungus to cacao from the roots of pois-doux and breadfruit, but records the occurrence of cases in fields from which shade trees were absent. He refers to the typical star-like web of white mycelium between bark and wood. He was not acquainted with any fructifications of the fungus.

F. W. South (1909-13) investigated and described in detail what he named the black root disease of limes and cacao in Dominica and St. Lucia, showed the identity or close similarity of the causative fungi on these and a large number of other host plants, and, by the finding of both conidial and perithecial fructifications, proved them to belong to the genus Rosellinia. Two kinds of perithecia were found, of which one type was identified at Kew as *R. bunodes*; the material of the other was immature and could not be determined, but by comparison with later collections is now known to belong to *R. Pepo*.

South was of opinion that infection with the fungus mainly takes place by root contact with previously infested trees or decaying logs, but he notes the occurrence of instances where trees become infected with no such sources near, and cases where there is room for the supposition that the fungus has commenced its attack on the collar just below the surface of the ground. South and Brooks (1912) say that the fungus does not appear to grow in decaying humus.

W. Nowell (1913-16). The present writer has studied Rosellinia diseases in St. Lucia, Dominica, Grenada, and St. Vincent. As mentioned in the introduction, five species have been found, and are discussed separately below.

II.—THE FUNGI CONCERNED IN ROSELLINIA DISEASES IN THE LESSER ANTILLES.

A. Rosellinia Pepo., Pat.

This species was originally described by Patouillard in 1908 from material on the bark of *Hymenaea Courbaril* collected by Duss in Guadeloupe. In the British Antilles the perithecia have been collected in Dominica, St. Lucia, and Grenada. From the published accounts of root diseases in Jamaica, Porto Rico and Martinique, it seems probable that the species also occurs in those islands.

Its most general importance is due to its attacks on cacao, but it is capable of producing destructive effects on any of the ordinary crop plants, herbaceous or woody, which are planted on land recently cleared from forest. Under such circumstances, limes in Dominica have suffered severely from this species, as well as from *R. bunodes*.

Where cacao trees have been killed by the fungus and other plants have been put in for temporary fillers, I have seen dasheens, bananas, pigeon pea, cassava, and horse bean all attacked. Sugar cane has several times been seen to survive, but I cannot say that it is really immune. Barber includes it in his list of plants affected.

Patouillard's description of the fungus is as follows (trans.) :—

Perithecia scattered or in groups, situated on the crustaceous conidia-bearing subicle, globose, somewhat stalked, 2·5 to 3 millimetres in diameter, dark brown, carbonaceous, furnished with a conical shiny black osteole, remaining closed, surrounded by a darker somewhat more flattened areole ; asci elongate, capitate at the apex, furnished with an ovoid pore, turning blue with iodine, much attenuated below, eight-spored, 10 to 12 microns in breadth ; paraphyses numerous, linear ; spores brown, straight, fusiform, pointed at each end, measuring 62 to 67 by 8 to 9 microns, at first increased at each end by a glassy halo, later bare.

There are present erect conidiophores (Graphium) 1 to 3 mm. in length, 30 to 60 microns broad, composed of brown septate hyphae 4 to 6 microns thick, situated on the crustaceous subicle. Conidia not seen.

The perithecia are borne, usually at the base of the stem, amongst and in succession to the conidial fructifications, on the somewhat carbonaceous layer which is formed on and in bark which has become thoroughly infested.

The perithecia are formed much less freely than in the case of *R. bunodes*, and in spite of long-continued search, material containing ripe asci has only once been obtained in the British islands : this was found by the writer on a dead lime tree in Dominica, in a situation with an annual rainfall of some 250 inches. Examination of this material at Kew enabled Miss E. M. Wakefield to identify the fungus as Patouillard's species.

The perithecia are normally slightly verrucose (Fig. 1) but are sometimes found smooth. Apparently this is due to weathering, though possibly (cp. *R. bunodes*) there is some variation in the amount of roughness developed.

The conidial fructifications are of the *Graphium* type figured by various authors in connexion with *Rosellinia necatrix* and other described species. They occur previous to the development of perithecia and are borne on the black surface mycelium which develops wherever the fungus reaches the open under damp conditions. Each has the form of a black bristle-like stalk 2 to 3 mm. long, built up of perpendicular hyphae which branch out freely at the top into a tuft, which is white or whitish to the naked eye from the conidia which cover it. The conidia are borne laterally towards the terminations of these branches ; the cells which bear them have a somewhat zig-zag or corkscrew appearance from their tendency to bend away from the point of attachment of a conidium. (Fig. 12, F.) The conidia are rounded or oval, one-celled, about 5 microns in length.

The conidial fructifications are developed in very great abundance (Fig. 2) and have been seen on dead leaves, twigs, and old lime skins lying under close shelter beneath infested trees.

The most striking characteristic of this species is the production of fans or stars of white mycelium in the region of the cambium (between bark and wood) of the roots (Fig. 3). The presence of these distinguishes it at once from *R. bunodes*. A somewhat similar appearance may be produced by the unidentified species (C), but in the examples of the latter fungus seen, the growth has been very much less vigorous.

On the roots the mycelium forms an irregular coating over the surface. In its early stages it is smoky grey in colour, but soon becomes black. It is gathered at first into rather loose branching strands with spreading hyphae between them. Later the whole is combined into a layer which is more or less woolly on the surface, and tending to be carbonaceous below. It forms dense layers and pockets in the outer bark, and from these whitish strands more or less vertical to the surface everywhere penetrate the cortex. On reaching the surface of the wood these repeatedly branch and spread in all directions over it, so that when 'bark' and wood are separated, a conspicuous white pattern of branching lines, stars and fans is seen on the surface of the wood and repeated on the inner surface of the 'bark'. From this layer strands penetrate the wood in radial lines along the medullary rays, and send out hyphae which invade and fill the large vascular elements. In this species the mycelium in the wood, owing to its lack of colour, is not apparent to the naked eye unless a cut surface is exposed for a day or two, when the hyphae grow out and turn black. In long-infested wood, thin plates, seen as black lines in a section, mark off certain areas, and are believed to belong to this fungus. Such plates, however, are very common in dead wood, and so have little diagnostic value.

The external mycelium is most fully developed and conspicuous when the fungus reaches the base of the stem and appears above the surface of the soil. It is then seen in broad spreading fans, or an advancing sheet, which from the beginning or at an early stage encircles the stem (Fig. 4). The margin while actively advancing is light grey in colour for a width of about half an inch, behind which the colour shades off to brown

or black with a greenish tint. On lime bark the sheet is smooth and glossy rather like wet fur.

The height to which the fungus reaches is determined by the moisture conditions. When the stem is well exposed it reaches no further than the few inches for which the moisture of the soil can affect it; if the stem is enclosed by weeds, or low branches, or sheltered by a log, it commonly goes up for a foot or more. In a case seen of a breadfruit tree growing against a bank 4 feet high, it extended upwards for that distance. The limit of the external mycelium is also the limit of the ultimate infestation of bark and wood. If a diseased tree is up-rooted, or is cut below the limit of infestation, and thrown aside where weeds grow up and shelter it, the fungus extends to the whole of the stem and branches thus kept moist.

In the rootstocks of herbaceous plants, as in thick soft bark the firm round strands of mycelium, buff-coloured without, white within, penetrate the parenchyma in all directions.

B. Rosellinia bunodes, B. et Br.

This fungus, as may be gathered from the preceding pages, is recorded as the cause of root disease of coffee, pepper, and associated plants in South India, of Hibiscus in Ceylon, of coffee and associated plants in Porto Rico. In the Lesser Antilles, South found it on Castilloa and camphor from Grenada, and on limes in Dominica. The present writer has seen it on *Hibiscus rosa-sinensis* in Grenada, on limes, Hibiscus, Acalypha and several unidentified native shrubs in Dominica. In St. Vincent a disease of arrowroot is caused by a Rosellinia the perithecia of which have not been obtained, but whose remaining characters are those of this species. There is no doubt that this list could be very considerably enlarged. I have not met with *R. bunodes* on cacao, but South (1912) records a probable instance of its occurrence on young cacao growing near diseased arrowroot.

R. bunodes is at the present time responsible, where proper precautions have not been taken, for a steady and increasing loss of lime trees on recently cleared estates in Dominica. Since however the species previously discussed is about equally abundant there on the same host, the records made previous to 1915 regarding black root disease of limes cannot usually be referred to one species as distinct from the other.

The species was originally described from Ceylon by Berkeley and Broome, and the technical description as given by Petch (1910 a) is as follows :—

Perithecia densely crowded, embedded at first in purple-brown mycelium, superficial, brownish-black, globose, up to 1·6 mm. diameter, carbonaceous, verrucose with close-set, somewhat pyramidal warts arranged more or less concentrically, ostiolum sometimes papillate, sometimes not elevated, wall of perithecium thin, brittle, about 0·1 mm. thick, black internally.

Spores, 80-110 × 7-12 microns, cymbiform, or sometimes lanceolate, ends acute and produced into a thread-like point which in the longer spores may reach a length of 25 microns, brownish-black, opaque. Asci not seen.

Asci in all stages have been seen in the Dominica material. Three representative examples measured gave lengths of 285, 350, and 357 microns for the whole ascus, while the portions occupied by the spores (8) were 250, 257, and 264 microns respectively. The linear paraphyses considerably exceed the asci in length. The number of ripe spores developed in an ascus varies from one to eight, but is very commonly eight. They overlap so as to form a more or less double row. The spores are very variable, especially in the length of the thread-like appendages, but the measurements made here fall mostly within the limits given by Petch.

The spores are exuded from the perithecium in a narrow thread without much cohesion, and lie in a clump on its summit. I have no evidence to offer as to the method or possibilities of their dispersal, but they would be easily carried away by heavy rain.

Under the conditions prevalent in the uplands of Dominica and Grenada the perithecia are formed very readily and in great abundance on the surface of exposed roots, around the base of the stem of infested trees, and on infested woody material lying about in damp situations.

They are easily distinguished by the coarse, more or less pyramidal warts with which they are densely covered. It should be noted, however, that in a single instance, in Dominica, perithecia of this species were collected, from a lime tree, which were little rougher than the examples of *R. Pepo* figured. As regards size, spores, and the very distinctive mycelial characters, there was complete identity with *R. bunodes*.

The conidial fructifications are of exactly the same type as those of *R. Pepo* described above, and I have not succeeded in finding any character by which they may be distinguished in the two species.

THE FUNGUS ON LIME AND OTHER TREES.

In respect of the general course of its development and in its main characters, *R. bunodes* closely resembles *R. Pepo.* There are however certain definite specific differences in the appearance of the mycelium which enable the two to be readily separated in the absence of perithecia.

At the point of infection on a lime root, the bark, normally yellow, takes on a greenish tint, and a dead patch extending to the cambium is formed in it. From this, the fungus spreads over the bark and through the cortex, the infestation of the wood following later. The mycelium on the surface consists mostly of closely applied, firm-textured, branching black strands which thicken into irregular knots along their course. On examples of Castilloa roots examined such knots (the sclerotia of some writers?) had formed over and infiltrated the large transverse lenticels, and on Hibiscus similar bodies in the form of dome-shaped papillae have been seen.

At a later stage (referring to lime) the space between the strands may fill in so that a dense layer is formed, which on its lower surface grows between and encloses the outer layers of the

bark, and on its upper surface bears in relief a closely ramified system of rhizomorphic strands. From the lower surface abundant cylindrical strands, with a black periphery and a white core, penetrate the cortex in a direction more or less vertical to the plane of the cambium. On reaching the wood they run for a short distance over its surface, and distribute themselves into it by vertical branches which penetrate by way of the medullary rays. From these the adjacent large tracheids are invaded and filled with bundles of parallel hyphae, hyaline at first, black later.

The result of this distribution is that the strands are seen in the wood of a transversely cut root as black dots and radial lines; in a median, longitudinal section as vertical and horizontal lines; in the bark as black threads of irregular length and course.

As in the case of *R. Pepo* the surface mycelium ascends the stem for some distance above ground as an encircling sheet. In this species the whole sheet when quite fresh may be creamy white in colour; it eventually turns black. The 'bark' beneath commonly remains healthy for some time after it has become covered, but it is eventually penetrated and killed. By the further development of the mycelium a sort of crust is formed on which the conidial fructifications and perithecia successively arise.

The characters by means of which *R. bunodes* may be readily separated from *R. Pepo* at any stage may be gathered from a comparison of Figs. 3 and 6, and by noting that in contrast with the condition shown in Figs. 9 and 10, the mycelium of *R. Pepo* does not show in the wood until very late, and then only in long zig-zag lines formed by cutting through a continuous black film or plate. There is only one caution to be observed: where *R. Pepo* has formed a crust on the bark and is fruiting, some blackening may extend to the mycelium under the bark at that point. The examination of a root will remove any uncertainty. In herbaceous plants the distinction between the yellowish white strands of *Pepo* and the black ones of *bunodes* is usually quite clear.

THE FUNGUS ON ARROWROOT.

The disease on arrowroot is a special case, brought into prominence by the estate cultivation of that crop in St. Vincent, of the general effects of *Rosellinia* spp. on herbaceous plants with succulent rootstocks.

In 1891 specimens of arrowroot rhizomes from St. Vincent affected by a disease known as 'burning' were examined by H. Marshall Ward at the request of the Director of the Royal Gardens, Kew (Ward 1893). They were reported by him to be badly affected by a subterranean fungus-mycelium, and to have produced conidia in the manner of the genus *Spicaria* when kept in a damp chamber.

No further outside attention seems to have been given to this affection until South, after a visit in 1911, gave an account

of it in a report (unpublished) made to the Commissioner of Agriculture. He described the disease as occurring in the fields in patches varying in are a from a few to several hundred square feet, and constant in position from year to year. The symptoms do not make themselves apparent until the rhizomes are nearly ripe for digging. At this time the affected plants have fewer leaves than the healthy ones growing in their vicinity, and these leaves are often rolled up and sowewhat wilted. Extension of the patch is very slow, but the fungus is very persistent, and the disease was reported to have reappeared in the first crop on a field replanted after remaining in bush fallow for twenty-five years.

Examples were seen of bananas, cassava, tannia, and yam similarly diseased, grown in ground known to be infected. Indian corn, pigeon pea, plantains, coffee and avocado pear were reported to be liable to infection. In a recent letter, W. N. Sands, Agricultural Superintendent in St. Vincent, adds Sea Island cotton to this list, and remarks that so far as he can judge, sugar-cane and Guinea grass are among the few economic plants which appear to be immune. He states that the disease 'is always present in wet interior mountainous places, but does not affect to any extent arrowroot at fairly low elevations near the coast.'

South (1912) did not find fructifications of the fungus, but noted the resemblance of the mycelium to that of a Rosellinia.

In 1915 the present writer visited a field in which the rhizomes had recently been dug, and were lying in small heaps on the ground. The material from a diseased patch was conspicuous owing to the black discoloration of the rhizomes. Towards the base cf the heaps sufficient moisture had been retained for the fungus to continue growing, and there were woolly tufts and strands of greenish grey mycelium, undoubtedly that of a Rosellinia, and an abundance of the typical conidial fructifications. Allowing for the difference in structure of the two plants, the appearance of the mycelium in the rhizome corresponds exactly to that of *R. bunodes* in lime roots, that is to say, the mycelial strands are identical, and their distribution throughout the relatively soft tissue of the arrowroot rhizome is identical with that seen in the bark of the lime (Fig. 6).

On the exterior of the arrowroot rhizomes as seen when they are dug, there is little or no loose external mycelium. When such does occur, the hyphae are of the usual 'varicose' type. On the surface of both rhizome and scale leaves there is a dense scatter of shiny raised dots and ridges (less than 1 to about 3 mm. in diameter) consisting of compact aggregations of dark hyphae in the superficial tissue. From these the slender compact branching strands, black with a white core, radiate through the parenchyma both of the scale leaves and of the rhizome.

In the latter they mostly follow a radial course, and are conspicuous to the naked eye as black dcts and lines in a section. At this stage the rhizomes are still full of starch. At an early time on the scale leaves, and later on the rhizomes, the black spots tend to run together until the whole surface is black and

shining, and about this time the parenchyma of the rhizome may be found generally infested with hyaline hyphae and depleted of its starch.

The fungus is certainly a Rosellinia. The identity in appearance of the internal mycelium with that of *R. bunodes*, and its difference from that of *R. Pepo*, supported by South's finding of perithecia of the former species in close proximity to a diseased patch, lead to the conclusion that the fungus is *R. bunodes*. This can only be more firmly established by the finding of perithecia on the arrowroot itself, or on plants infested from it under control.

C. Rosellinia sp.

Reference has been made to an undetermined species of Rosellinia occurring on cacao trees in Grenada and St. Vincent. The perithecia were first found by the writer in 1914 on the wood of an Erythrina log on a cacao estate near Soufrière, St. Lucia.

During a visit to Grenada in 1915 several groups of trees were met with, which although growing in apparently good soil and in favourable situations were dying out. The appearances were such as to suggest root disease as the cause. The district in each case was in the drier lowlands where the disease due to *Rosellinia Pepo* seldom if ever occurs, and some of the characteristic features of that disease were absent. The trees were slowly dying back from the top, and putting out new suckers from below, which in turn failed until the tree was completely dead. In various stages of this process examined, the collar and upper roots bore no sign of disease, but on the lower roots a mycelium was found which formed a white radiating pattern between bark and wood closely resembling that of *Rosellinia Pepo*, but much more scantily developed. These differences might have been put down to the effects of drier conditions had not the finding on dead cacao trees in two of these localities of the perithecia of a distinct species of Rosellinia, associated with a similar scanty white mycelium, brought the existence of a separate, though closely allied, disease into question.

In one instance of a diseased group, the only one on an otherwise healthy estate, the trouble seemed to have had its origin some six years previously in the felling of two examples of the tree known in Grenada as *tendre acailloux* (*Piptadenia peregrina* ?); in the others, no such source was apparent. In another instance, I was informed that bananas planted as cover where trees had died never reached the bearing stage, and I saw examples of banana plants in various stages of a root disease which may have been due to a Rosellinia, but which I could not recognize as such.

Some confirmation of the view that this species of Rosellinia attacks cacao was obtained on an estate near Georgetown, St. Vincent, where it was found fruiting abundantly on dead cacao trees occurring in patches suggestive of the effects of Rosellinia disease. No other species was detected in this

situation, but as trees were dying out on other portions of the estate from causes attributed to exposure and impoverishment of the soil, with consequent heavy infestations of thrips, the evidence obtained in the limited time at my disposal was not conclusive. The degree of parasitism of which this species is capable requires to be established by further investigation, but on the Grenada evidence the conclusion that under certain circumstances it can produce a root disease of cacao seems justified.

As seen so far, the disease is much slower in its action than that due to *R. Pepo*, and the failure of the trees much more lingering. It is capable however of existing under conditions of relative dryness such as appear to exclude the more familiar form.

The fruiting habits of the fungus are the same as those of the species already described, and the conidial fructifications have the same form. The perithecia form a dense layer on the surface of the wood, looking like fine shot dusted thickly upon it. They are shown, enlarged, in Fig. 11, and an ascus is represented in Fig. 12, E. Complete material has been forwarded to Kew for identification or description.

D ROSELLINIA (BOTHRINA, B. ET BR. ?).

Abundant fertile perithecia of another species of Rosellinia were found by the writer on the bark of cut branches of an Erythrina near Soufrière, St. Lucia, in 1914. Submitted to Kew, the fungus was reported by Wakefield to be 'probably *R. bothrina*.' There was no evidence of any disease associated with its occurrence.

As collected, the brownish-black perithecia are situated in dense clumps, on clean light-brown bark with scarcely a trace of mycelium. They are globose, 1·5 to 2 mm. in diameter, smooth and shining to the naked eye, but with some slight traces of verrucosity when viewed with a lens. They are topped with a small conical papilla. The spores range from 35-50 × 5-8 microns.

R. bothrina, which is a Ceylon species, is described by Petch (1910) as follows:—

Perithecia gregarious, embedded at first in dark purple-brown mycelium which subsequently weathers away; at first blackish-brown, with a black ostiolum, then black; superficial, carbonaceous, globose, slightly depressed, 1·5 to 2·4 mm. diameter; smooth (fragments of the mycelium adhere at first to the perithecia, but these soon disappear); ostiolum conical, 0·1 mm. high, springing from a base 0·4 mm. diameter; perithecial wall brittle, black throughout, rather thin, about 0·1 mm. thick. Asci about 300 microns long, 8 microns diameter, cylindrical, spores obliquely uniseriate or almost uniseriate; paraphyses filiform, about 2 microns diameter, as long as the asci. Spores 40-47 × 5-7 microns, guttulate, finally opaque, black, cymbiform, ends pointed and often abruptly narrowed in the last 3 microns.

The account given of the mycelium of this fungus and its mode of action as a parasite shows that in these respects it bears a very close resemblance to *R. Pepo*.

Its principal importance in Ceylon lies in its causation of a root disease of tea. Erythrina is mentioned as subject to its attacks.

E. ROSELLINIA (SUBICULATA (SCHW.), SACC. ?).

Another Rosellinia was obtained in the same district of St. Lucia as the one last mentioned, on a cacao estate some miles further inland, again on Erythrina, a cut log. The material collected consisted of perithecia only, and was reported by Wakefield to be 'apparently *R. subiculata*, but with the subiculum not evident, as is sometimes the case.'

The perithecia on the specimens in question are borne on bare wood, are very small (near 1 mm.), sessile, dome shaped, with a small central papilla, nearly smooth, in colour dull brownish-black. The ascus and spores are shown at B in Fig 12. The average measurement of the spores is 13 × 8 microns.

No evidence was obtained of the association of the fungus with any disease, and I have at present no references to previous accounts of the species *R. subiculata*.

III.—MODE OF OCCURRENCE OF ROSELLINIA DISEASES.

As seen in the West Indies, the diseases due to Rosellinia, with the exception of that on arrowroot, occur: (a) on land recently cleared from forest, still containing the dead and dying stumps of the forest trees and retaining a considerable amount of the forest humus; (b) in cacao cultivations, the conditions in which, especially where shade trees are abundant, approach more or less closely to those of forest in respect of shade and humidity; and (c) in wind-breaks and hedges of certain susceptible trees in wet districts. The prevalence of the diseases is very distinctly governed by humidity. The types due to *Rosellinia Pepo* and *Rosellinia bunodes*, which alone have any considerable economic importance, are most virulent in the wet uplands of Dominica. St. Lucia and Grenada; the former follows the cacao cultivations down the more sheltered valleys to the coastal districts; the latter has not been met with away from the hills.

THE CENTRES OF THE DISEASE.

a. IN NEW CLEARINGS.

The fungi concerned have not been found in a purely natural habitat, i.e., in undisturbed forest, although sought for to some extent. From the mode of their appearance in recent clearings there can however be little doubt of their existence there as a part of the natural flora.

It is the usual custom in these islands, when clearings are made, to burn as much as possible of the smaller material, but to leave the logs on the ground to rot, and to make no attempt to remove the stumps. Many of the latter send up suckers

which have to be cut away from time to time. Under these circumstances it takes very many years before the logs and stumps finally disappear, and during the course of their decay they make the soil around them dangerously rich in crumbling woody matter and humus.

On land so prepared, as soon as the felling and burning are finished, nursery plants are set out in the spaces between the stumps and logs. To get anything like regularity of stand many have to be placed close up to these obstacles. The writer has not seen new plantations of cacao, but has had ample opportunity in Dominica for examining all stages of lime cultivations thus begun.

Fungi are of course very abundant on the decaying material, but the Rosellinias are far from being conspicuous among them. I have once found in Dominica a large decayed log infested with the mycelium of *Rosellinia bunodes*, as shown by the infection at the point of contact of lime branches touching it, and infection of a shrub growing upon it, and have found species C, D, and E on Erythrina logs in a St. Lucia cacao cultivation.

Nor have the Rosellinias been found so often as might have been expected on forest stumps. In a fruiting condition they are in fact rare in this situation. The most notable case I have seen was that of a chataignier stump (*Sloanea* sp.) covered with perithecial and conidial fructifications of *R. Pepo*, which from its position appeared to be the centre of infection of a large group of diseased limes. The presence of the mycelium on the buried roots of forest stumps is more frequently observed. Every infested clearing shows examples of the association of diseased trees with stumps, and sometimes these are very striking, as when a group of five or six dead and dying trees is seen around a large chataignier. The actual nature of the connexion is usually difficult to demonstrate; as a rule the cases when seen are too far advanced for sure conclusions, and often they have to be passed over for want of time or means for the uncovering of the roots. But from first to last a good many cases have been investigated in which the roots of diseased trees have been found in contact with roots of forest stumps bearing the fungus. In some of these the evidence that the fungus passed from the stump to the lime tree is quite definite. Two examples in which the evidence includes the identity of the forest tree may be cited. South (1913) reports having followed up the fungus from dead mahoe cochon (*Sterculia caribaea*) to the roots of a living lime tree; the writer examined a large stump, still bearing a few living suckers, of chataignier grand-feuille (*Sloanea Massoni*) the roots of which were badly infested and had recently communicated the fungus to the roots of a lime tree in contact with them. In other cases a single root coming from the direction of a stump has been found to be infested when all others were sound. From the nature of the case, examples in an early stage are only found by accident or a lucky shot, so that one is justified in assuming that a fair proportion at least of infections near stumps take place in this way.

The fact remains that considering the area of the clearings, the number of infested stumps does not appear to

be large. Relatively few trees are lost in the first three or four years after planting. This is in part due to the time taken (a) by the fungus to develop on and about the stumps, (b) by the roots of the planted trees to grow out into the infested area, and (c) by the fungus to kill a tree after infection. But observation shows that when the period of heavy losses ensues, most of the trees are infected from one another, so that the characteristic distribution of the disease is in scattered patches whose number is very small compared with that of the stumps and logs in the clearing.

There is strong reason to believe, and the idea is supported by experience in other countries, that the number of forest trees whose stumps readily serve as centres of distribution for the fungus is quite limited, and that the presence of the stumps of these especially susceptible trees in clearings has a good deal to do with the appearance of the disease. It is a well-known fact, already referred to above, that there is such a special susceptibility in the case of certain cultivated and semi-cultivated trees. Accurate information as to the identity of the forest trees most concerned is difficult to obtain. By no means all the forest trees have been identified, and to such as have, the patois names which form the connecting link with local knowledge are often loosely applied. In Dominica a large number of cases certainly occur in connexion with deeply buttressed stumps commonly referred to chataignier, a name usually identified with two or three species of Sloanea. One planter has suggested that the closely similar stumps of bois cote are in his district more commonly the source of the trouble. Infection from the roots of mahoe cochon (*Sterculia caribaea*) and chataignier grand-feuille (*Sloanea Massoni*) in Dominica has been already mentioned. South and Brooks give mahoe piment (*Daphnopsis tinifolia*) and bois cabrit or goatwood (*Algiphila martinicensis*) as susceptible trees in St. Lucia. The perithecia of *R. Pepo* were described by Patouillard from locust (*Hymenaea Courbaril*) in Guadeloupe.

The disease is unknown in the older lime estates, which have no recent clearings. This cannot be regarded as wholly due to the much lower rainfall which most of them receive, since even near the coast lime trees contract the disease when planted as substitutes for diseased cacao. There is moreover at least one forest estate in the same district as some which are badly affected, where the clearings are old enough for the stumps to have disappeared, and where, in the limes which have replaced the crops first planted, root disease has given no trouble. In comparing this position with that of cacao cultivations, in which the disease due to *R Pepo* is very liable to appear after they have been long established, it has to be remembered that the canopy is not so dense in a lime field, and that shade trees are not grown.

b. IN CACAO CULTIVATIONS.

In the great majority of cases the disease occurring in cacao has its origin in the trees grown for shade. When these are cut out, as often becomes necessary as they get too large, the stumps

are left to rot and a condition is produced comparable in essentials with that in the clearings just discussed. The danger is well known to planters, especially with regard to breadfruit and avocado pear trees. A Grenada planter of long experience claimed that on several occasions when root disease had appeared in his cacao he had been able to trace it to the decay of bread-fruit roots cut through in digging drains. I have seen the fungus on stumps of cacao trees which were healthy when cut down in thinning operations.

Apart from this, trees of the kinds named are rather liable to die of their own accord. How often this is due to their contracting Rosellinia disease, and how often they become infested with that fungus only after the death of some or all the roots from other causes, I can form no opinion. When, as often happens, the stumps are those of healthy trees, cut down for other reasons, obviously the latter is the case. The observed facts as they regularly present themselves are these: that one or more of the cacao trees immediately adjacent to a sickly or a dead shade tree, or shade tree stump, begin to show symptoms of root disease, and removal of the soil reveals the fungus advancing along one or more of the cacao roots from the neighbourhood of roots of the shade tree, which are found to be infested, and usually in an advanced stage of infestation. Sometimes actual contact has been proved, sometimes not. In view of the difficulties of digging among roots the negative evidence has not much weight. The trees most often concerned in connexion with the disease on cacao are avocado pear, breadfruit, and pois doux (*Inga* spp.). Immortel (*Erythrina* sp.) and mango are sometimes but not often involved.

The fact should be mentioned here, though its discussion belongs rather to the next section, that the disease can occur on cacao trees in the absence of stumps or any obvious dead wood. Cases of this nature are as a rule uncommon, but in one badly infested area examined a fair number were seen.

Methods of Infection.

Several of the authors cited in the first part of this paper refer to the spread of the fungus through the upper layers of the soil and in accumulations of decaying vegetable matter on its surface, resulting in the infection of trees at those levels. The usual mode of occurrence of the disease in West Indian cacao plantations does not bring out this feature at all clearly. With the exceptions alluded to above, the disease is generally clearly traceable to dead roots, which are often deep underground, and its course is along one or more of the cacao roots in the direction of the stem. All stages of the process have been seen, and quite commonly in the less advanced cases the crown is found still unattacked.

While a considerable proportion of the cases occurring on lime trees in the forest clearings correspond in character with the type just described, a close survey of two groups of 100 trees, which with the assistance of Mr. G. A. Jones I have carried out in Dominica, has clearly demonstrated the occurrence in

many cases of infection from the soil in the neighbourhood of the collar.

The following examples are taken from notes made on the spot :—

October 1914.	May 31, 1915.
A 7. Foliage healthy, collar sound, one small diseased root (*R. bunodes*) attached to collar. (Root cut away.)	Two more short roots attached to collar diseased. Collar bare and clean and remains healthy. Eighteen inches from stem a small root passing through one of the main buttress roots is diseased up to the point of enclosure. (Roots cut away.)
C 2. Foliage healthy, a large tree; one of the four large buttress roots diseased (close to the collar) also the bark of the collar in the recesses adjacent. A vertical root visible in the next recess is also diseased. (The earth was removed from around the crown, which was left exposed.)	Top still perfectly healthy. The two diseased roots and the bark of the adjacent patches on the collar are now quite rotten and covered with conidial fructifications, with a few perithecia (*R. Pepo*). The diseased area does not appear to be any more extensive than on the last visit, and the other roots have thickened up and replaced those diseased. The margin of the diseased patch is now followed all round by a line of healthy callus. The bark of the roots attached to the diseased areas is fully diseased above, *but from 2 to 3 inches below soil level it is healthy downwards*. The trees on all sides are vigorous.
C 3. Foliage healthy; collar sound; one small diseased root attached to collar, is dead to its base. (Root removed.)	Free from any trace of disease.
C 4. Foliage healthy; small diseased patch on collar with no connexion with any remaining root but could have arisen like C 3. (Cut out.)	Free from any trace of disease.
C 5. Local infection of bark on a buttress root at a point where it is crushed by a small root crossing over. (Cut out.)	Free from any trace of disease.

These cases demonstrated the occurrence of collar infection, in two cases by way of small late roots near the surface of the soil, in one possibly by direct infection of the bark of the collar. The trees were re-examined in August 1916, when they showed no further sign of disease.

It would be much more laborious to systematically examine the outlying roots running in the surface soil, but there is little room for doubt that similar infections would be found to occur upon them.

The cases sometimes met with of cacao trees becoming diseased in the absence of stumps can be accounted for by infection of the surface type just described. Proof of this was obtained in the area referred to in the preceding section, where several cases of this nature were seen. A living root was found which had been injured where it came to the surface, and from two points on the margin of the injuries white fans recognizable as the mycelium of *R. Pepo* were found radiating under the bark. This example is illustrated in Fig. 5. The cases noted have been in the wettest districts, where production of organic matter is at a maximum, and where cloudy days, the depth of shade produced by luxuriant growth, and the saturation of the soil with water, all reduce the rate of its destruction. Where rainfall and shade are not excessive, the addition of organic matter to the soil does not keep pace with its decay, and the general run of soil on the ordinary cacao estate is not particularly rich in humus, nor is there much, if anything, in the way of leaf mould on its surface.

The spread of the disease along closely planted hedges and wind-breaks, of which some striking instances have occurred in St. Lucia, is characterized and probably mainly effected by infestation of the surface soil. The leaves and twigs which accumulate along the base of the wind-break, and decaying, enrich the soil with humus, and the shelter afforded by the trees and by the vegetation which grows up under their protection provide conditions especially suitable for the fungus. It creeps along the line like a smouldering fire, killing off the trees and their seedlings, and most of the shrubby and herbaceous vegetation, as it comes to them. In a gap so produced, from which the stumps had been removed, a line of living fence posts subsequently put in consisting mostly of white cedar (*Tecoma leucoxylon*) were three months later infested to soil level. Wind-breaks of pois-doux and galba (*Calophyllum Calaba*) are very susceptible to the disease.

The evidence thus shows clearly that the spread of the fungus may take place in two ways : (a) underground along the roots of diseased trees or infested stumps, in which case one or more outlying roots of the new contacts are usually first infected and the fungus travels along them to the collar, infecting other roots as it crosses them ; (b) by the growth of the fungus through rich and damp (which usually means shaded) surface mould and vegetable debris, in which case the fungus first attacks surface roots or directly infects the collar.

How the infection originates is not known. Tradition, the whole course of planting experience, and many definite observations by agricultural officers, combine in associating the first

outbreaks which occur with the presence of stumps in new clearings, and of dead or sickly shade trees in older plantations. The theory as to the general course of infection which seems to the writer to best fit the facts at present known is this: (1) that the fungus is able, by means of its spores (of which the conidia are by far the more abundant and the more likely to be distributed by the wind) to infect any accumulation of decaying vegetable matter in damp soil; (2) that the required conditions are most often presented in the immediate neighbourhood of mouldering logs and stumps; (3) that a surface infestation thus begun may or may not communicate the disease directly to the cultivated trees: in the earlier stages of a plantation the chances are considerable that it will not, owing to (a) disturbance of the humus-bearing surface soil in planting the trees, and (b) the lack of shade conducing to rapid destruction of organic matter in the soil around; (4) that infestations round about the stumps of certain trees, on the other hand, are communicated to the roots at and about soil level, the fungus finding in the buried roots a food supply situated in permanently congenial conditions, so that it is able to follow them out to their extremities however far and deeply they may run, thus establishing a long-enduring and wide-spreading source of infection for the roots of cultivated trees which extend into contact with them.

As the trees grow large and produce a deeper shade, so protecting and keeping moist the organic matter which accumulates beneath them, the conditions for surface infection are greatly improved, and by this time, owing to the production of spores on the remains of the trees previously killed, the chances of any suitable patch of soil becoming infected are much greater. At this stage, therefore, the proportion of cases originating by direct infection from the soil will have risen, and such cases may in time far outnumber those associated with stumps.

Another type of situation continuously capable for a long number of years of becoming infested is presented by the soil on the shaded underside of logs, the disintegration of which, especially that due to the tunnellings of insects, maintains a plentiful supply of organic matter.

Once the disease has got a footing however, the greatest amount of loss is caused by the spread of the fungus along the roots (as it commonly appears) or over the surface (where conditions of shade permit) from one cultivated tree to others about it in an ever widening circle. In one case the loss of about 150 trees appeared to be clearly traceable to two original centres of infection.

Wherever a tree has died, unless strict measures have been taken to control the fungus, the adjacent trees almost inevitably contract the disease sooner or later. Such cases may arise years after the original tree has been removed and the cause of its death forgotten, so that they have the appearance of being sporadic. Examination of the position and age of supplies, and the keeping of records of surveyed areas enable them to be linked up with considerable certainty to previous losses. How far such belated cases are evidence of the slow progress of the

fungus along the roots, or how far they are due to delayed infection has not been ascertained, but the general evidence points to the conclusion that the process of investment of mature trees is a distinctly slow one. In a case definitely recorded, a fully infested dead lime tree was removed in October 1914, and the fungus (*R. bunodes*) was just coming up round the collar of the next tree in the row, a very large and vigorous specimen, in August 1916. The variety of circumstances must produce wide differences, but I should judge that the two years taken in this case is not an unusual period, and is in some cases considerably exceeded.

Typically an infested clearing in which the disease is of several years' standing shows a few large open patches, each representing perhaps a score of trees, with usually two or three around its margin dead or dying, and several more on which the fungus may be found. Sometimes two or three such patches have coalesced. Scattered about are fresh centres in various stages: a single tree, a gap of two or three trees in a row, with another going, or a group of two or three in different stages about a large stump. Of the supplies put in, some are several years old and still thriving, others are dead within a few months of being planted.

Appearance of Diseased Trees.

As the disease is seen on lime and cacao trees there are two types of failure of the top. In the one, where the roots become more or less generally infested before the fungus gets fully hold of the collar, as commonly happens where its approach along the roots is checked by drier conditions around the crown, defoliation is gradual and is preceded by yellowing of the leaves and a general sickly appearance of the tree. In cacao especially, this is the common form of failure and resembles a severe type of die-back, such as is brought about by poverty of soil or exposure. The development of vigorous suckers excludes *R. Pepo* as the cause of such a condition, but their non-development on failing trees does not necessarily indicate its presence.

The second type of failure, common on lime trees in the districts indicated, and occurring sometimes on cacao, is produced when the stem is girdled by the fungus while most of the root system remains yet uninfested. In lime trees the earliest outward sign of the disease in such cases, so far as I have seen, is the production of an abnormally large crop of fruit. Presumably the production of flowers would be equally striking, but this I cannot say from observation. Before this crop of fruit has had time to ripen the foliage drops, often with such suddenness that the ground is carpeted with leaves still green. The appearance which the tree then presents is a familiar one in the affected districts: its branches nearly bare of leaves and hung with shrivelling and prematurely yellow limes. In an observed instance a tree of perfectly healthy appearance, with abundant dark foliage, was found on October 20 to have its bark all round and for some distance up the stem infested through and through with Rosellinia; it remained green until November 17, and then the change from healthy foliage to naked twigs was completed in from twenty-four to thirty-six hours.

When relieved from loss of water by the fall of the leaves a tree may put out a few small shoots and linger for some time before it completely dies. It often happens that as the bark near the soil level is killed, tufts of adventitious roots are pushed out from a callus formed at the edge of the sound bark above. Quite a dense mat of small roots is formed, some of which may get a good hold of the soil and thicken up. This sometimes enables the tree to struggle on a little longer, and even raises hopes of its recovery. Such an event is very improbable, as the new roots soon become infected after they reach damp soil.

Incidence of the Disease.

The disease as seen on the Dominica lime estates is by no means regular in its incidence. It is a matter of general and rueful experience that it develops its attacks most widely in the best clearings, and that the finest trees, which is to say those growing in the deepest and richest soil, are the most liable to be infected. In clearings on thin soil and on the considerable area of upland flats where the soil is underlain by a stony 'pan' which prevents anything like adequate drainage, diseased trees are rare, and do not as a rule lead to further extensions unless they happen to be situated in a deeper pocket in the one case, or on a drier slope in the other.

These experiences are exactly paralleled in Porto Rico, where 'the disease often does most harm amongst the best trees, the sun-exposed slopes of poor coffee plantations remaining quite free from trouble.' 'The only things which retard or stop its progress seem to be excessively dry or excessively wet soils, natural barriers, such as brooks, and the scarcity of food material (decaying vegetation) in the soil.' (Fawcett 1915.)

This is not to say that slow-growing stunted trees are at all resistent to the fungus. Where the roots of such trees happen to come in contact with infested material they are killed as readily as any others.

The explanation of this feature of the disease is to be found in the favourable conditions of shade, moisture, and abundance of organic matter, produced by the heavy canopy of well grown trees. It is in such situations that soil infections, without the intervention of stumps, are very liable to occur. The comparative rarity of cases in the clearings on thin soils is in keeping with the theory put forward that the original sources of infection in any clearing are few in number. In poor clearings the cases mostly remain restricted to these. Something may be due however to the difference in the constitution of the original forest.

In cacao plantations the conditions are usually more uniform, and differences in the distribution of the disease are not well marked. There is however a noticeable tendency for outbreaks to occur along the course of ravines and on small enclosed alluvial flats. Among cacao, in the situations so far studied, infection apart from contact with stumps or diseased trees seems, as already remarked, to be relatively rare.

The Disease on Arrowroot.

The circumstances connected with the growing of arrowroot, the plants of which are annually dug out and in great part removed, produce in the features of its Rosellinia disease, as compared with those described in connexion with limes and cacao, differences which require separate consideration.

The special characteristics are: (a) that the disease occurs in patches which are reported to show little or no observable increase from year to year; (b) that in such patches the disease persists for a long and apparently indefinite period of years.

The explanation of these features is probably to be found in the methods pursued in arrowroot cultivation. The fields are usually kept in this crop for many years in succession, and although the crop is an annual one, the ground is never clear of plants. In the first place it is impracticable to remove the smaller fragments and offshoots of the rhizomes from the ground, as shown by the large number of plants which spring up after a change has been made to some other crop; and secondly, it is the custom when digging the rhizomes to break off pieces and return them to the soil, to serve as plants for the succeeding crop. The persistence of the disease, under suitable circumstances of soil moisture, may with great probability be thus accounted for, and it is helped by the custom of leaving the diseased rhizomes to decay on the spot. The fungus attacks the plants of almost any crop which succeeds arrowroot on the diseased patches, but I have no information of its persistence on such a crop after the arrowroot has been completely eliminated.

Its origin, as regards the primary patches, probably goes back to the cases appearing, as in lime cultivations, when the land was cleared of trees. One can readily conceive of secondary patches occurring, due to careless disposal of diseased material, or to the germination of spores on any accumulation of decaying tops or weeds sufficient to give the fungus a start.

Accurate and systematic observations, involving measurement of the extension of the patches, are wanting, but it does not appear, from the evidence available, that the fungus makes much progress from plant to plant in the soil, and there are no spreading roots to conduct it as in the case of tree crops.

IV. COUNTER MEASURES.

Prevention.

IN NEW LIME CLEARINGS. It would be a counsel of perfection to recommend the removal of stumps or even of logs from new clearings in their earliest stages. In West Indian plantations such a policy is not economically possible. But in arranging and planting new clearings for orchard crops, the probability that root disease will occur should be kept in mind, and certain precautions can be taken which will considerably reduce the trouble to be faced when disease appears.

First among these is provision for the construction, immediate or when occasion and funds permit, of a complete and close system of trench drains. To this end the arrangement of the trees should be planned so that each block shall be isolated from the rest by main drains and, where possible, each row separated from the next by a trench. There will be many patches encumbered with logs and stumps over which for some years the system will extend only in the plan, but it is necessary to take long views, and too many cases have been seen where, when the need for a trench has urgently arisen, the line has been brought up against trees irregularly planted and now too valuable to be destroyed. Drains are being considered here, of course, not in view of their primary function of removing water, but as isolation trenches preventing the spread of root disease from tree to tree. At the same time, thorough drainage may be considered to have direct value from the point of view of Rosellinia disease, for although, as has been pointed out, the fungus does not thrive in water-logged soil, neither do the trees, and when that condition has been passed, the drier the soil can become the quicker is the decay of organic matter and the less favourable the conditions afforded to the fungus.

It has been not uncommon in both lime and cacao fields when a large stump has appeared to be a centre of disease, for a trench to be dug around it cutting off the widely extending roots. When the fungus has already got into the root system this measure usually comes too late, but if it is applied to large stumps at the outset, especially to those of susceptible species, it may be expected to have some success. Possibly a variation recently suggested by A. Sharples (1915), namely the following out of each main root separately and removal of a section where it gets down to about 2 feet from the surface, may have the advantage over a trench that the cut ends are not left open to infection. On the other hand, without trenching all round it cannot be assured that all the roots are cut, and the smallest is capable of conducting the fungus outward or inward, as the case may be. The best plan would probably be to dig a trench some 2 feet wide well away from the stump, remove all sections of roots, and fill it in again.

In planting the trees, positions in close proximity to stumps should as far as possible be avoided, and a good deal may be done in the way of rearranging the smaller logs so that they do not form too close a shelter about the stem of the prospective tree. Beyond these measures little, for the time being, can be done. If the theory that the sour orange stock is more resistant than the lime is shown by the experiments now in progress to be well founded, then it will be advisable to plant such situations as experience has shown to particularly favour root disease with limes budded on that stock.

When the first few years have passed and the logs are more or less rotted, it has been shown to be quite feasible to hasten very materially the time of their disappearance by cutting or breaking them up so that they can be easily handled. Merely to dispose of them better by dragging them away from the stems of the trees is a considerable gain, and in some cases it has been

found possible to stack much of the material, and even to make good use of it for fuel. The great convenience, quite apart from root disease, of having the ground clear should be an additional inducement to the planter to make every possible effort to this end.

A point to be always kept in mind is that wood which can dry out from time to time, e.g. logs, stumps, or parts of them which are raised above the soil and not shut in by weeds or overhanging branches, is in little danger of harbouring the fungus.

The same consideration applies to the soil. In damp and sheltered clearings such as are favoured by the fungus, all that is possible should be done to encourage the free circulation of air beneath the trees. Low hanging branches which maintain a closely sheltered circle around the base of the tree induce conditions which invite surface infection, and should most certainly be cut away. Grass and weeds should be kept short all the time, not merely in the crop season.

It is highly desirable in infested clearings, and especially in the neighbourhood of infected spots, to go further and clear away the soil and weeds about the base of the stems, completely baring the collars, and liberally exposing the main roots so far as this may be done without forming a saucer in which water will stand. The treatment of the collar and the recesses between the roots with lime-sulphur solution to keep the bark free from moss gives an added protection of considerable value.

All these measures are summarized in the word ventilation, and cannot be too strongly emphasized. The fungus cannot tolerate dry conditions, and it is for the planter to take every advantage he can of this weakness.

IN CACAO PLANTATIONS. There are probably few managers of cacao plantations who would nowadays plant breadfruit or avocado pear trees through their fields. The idea of the more economically minded of the old planters seems to have been that since shade trees were to be grown, they might as well be such as would give something in the way of food in return for the room they occupied. The modern idea of the manurial function of shade trees leads to a preference for leguminous trees, and justifies the more orthodox tradition which led to the planting of immortelles. Where pear and breadfruit trees are already established, the planter who has learnt respect for the root disease has two courses open to him. The one is to take the utmost care of such trees, to prune out dead branches, to avoid injuries to the roots, and generally to try to preserve them in health as long as possible; the other is to take them out as occasion offers, removing the stumps, and following out and removing every root that can be got at. This is usually difficult because of the adjoining cacao trees; where the trees to be dealt with are large, it becomes formidable. The easy course is to cut down or ring the trees, and leave the roots to rot, but that way trouble lies. It does not always happen, but striking, one might say startling, cases have been seen where the cutting down of a pear or breadfruit in the cacao, or a pois-doux by the roadside has led to the appearance of the

disease in places from which it was thought to be far removed. These three trees are the chief victims, but there is none that can be considered to be really safe. It should be the settled policy of cacao planters in wet districts to leave no woody material to rot in the soil if it can possibly be avoided. Where there is deep shade and high humidity, any vegetable matter used as mulch may be a source of danger, though one that may have to be risked in view of manurial requirements. The more careful and prompt the attention that is given to any appearance of the disease on the plantation the less will the risks of this nature be.

With regard to wind-breaks; where experience has shown that there is danger of disease arising, it is advisable to keep them as free as possible from undergrowth, and to scrape away any accumulations of leaves or other material from hollows or other sheltered places. This might be used as mulch in dry places, or preferably, if there is a pen near, for the making of pen manure.

TREATMENT.

In a recent pamphlet (1915) the writer has stated that attempts to cure infected trees may be put aside as in most cases hopeless and in the remainder doubtful, and as involving so much skilful surgery as to make them impracticable on any but the smallest scale. Addressed to the planter as he has usually been found, concerned with matters of primary urgency and with very inadequate assistance, the words may still stand. As regards trees with deep-seated or well-established infections there is indeed no more to be said. But actual experience, as illustrated in the cases previously detailed, has shown that in fields in which the disease is established and surface infection is taking place, an examination of the trees, involving no more than an initial clearing and periodic inspection of the crown and collar, will directly save many lightly infected trees, and indirectly, by preventing the formation of new centres of distribution, save very many more. All that is needed is to have the lower branches pruned sufficiently for access to the trunk, a couple of labourers to go on ahead and clear away weeds and earth for a foot or so around the junction of roots and stem, preferably using their hands or a blunt instrument to avoid wounding the bark, and then to make a few minutes' investigation of each tree so prepared. In addition to saving trees, such a system enables the hopeless cases to be detected long before they otherwise would be, and makes it possible to deal promptly with them. One is justified here in being insistent and saying that in every clearing in which the disease has become established, such an inspection ought to be made at least twice a year. It is after all a mild proposal.

The principles of the actual treatment required are two in number, and very simple: (a) complete excision of diseased tissues; (b) exposure as complete as possible of the affected part and its surroundings to freely circulating air, with the object of making the conditions too dry for the fungus to exist. In operating it must be remembered that after the early stages the fungus penetrates wood as well as bark. It is the drastic surgery

made necessary by this fact, and the propensity of the fungus for lateral spread in the outer zone of roots, that make the saving of cases at all advanced so hopeless. Commonly in such a case a great part of the root system has to be cut away, and the roots severed in the operation and left behind give every opportunity for the disease to reassert itself.

The cases which repay treatment are those arising from surface infection, in which on inspection the local nature of the infestation appears to be clearly defined. Severed roots should as far as possible be removed; cut surfaces should be cleanly trimmed and dressed with paint; excavations made to get at the seat of injury should be left open. It should be hardly necessary to say that the material removed must be carefully disposed of. These directions may give rise to an exaggerated idea of the elaborateness of the treatment required. They are fully applicable to cases such as that of C2 described, which was close to the margin of possible recovery, but in many cases a few cuts with a sharp knife will save a tree from an infection which would have meant its certain death.

Where the disease has been detected advancing along one or more large roots but has not reached the collar, and it is desired to give the tree a chance of recovery, then after the diseased roots have been cut away, as much soil as possible should be dug out about the junction of the main roots and as far back as they can be conveniently followed, leaving the tree more or less on stilts as it were. This prevents the crossing over of the fungus at or near the collar, and may very considerably delay the loss of the tree, but if the fungus, as is probable, exists on the outer roots, it will in time get round in that region and come up each of the main roots in turn as far as the point to which it has been bared. It is not a measure to be recommended. It is better to have the tree out and be rid of the fungus, but the temptation to get an additional crop or two from some specially fine tree is sometimes hardly to be resisted.

The directions here given as to treatment apply equally to limes and to cacao, but as has been previously indicated, with the latter crop, so far as the writer's experience goes, the cases are more usually of the deep-seated kind, which does not permit of successful treatment.

CONTROL.

REMOVAL OF DISEASED TREES. When an infested tree is found it is well that its destruction should be prompt, but it is an advantage to choose a dry day for the operation. If the disease is so far advanced that the fungus is producing conidia, either on the stem or on dead leaves and twigs lying about, then before it is disturbed the spore-bearing surfaces should be flamed with a torch or by burning trash of some description around them (Petch 1910 b). This disposes for the time being of the means of aerial dispersal of the fungus, and removes what is otherwise a real danger of the carriage of infection on the persons and implements of the labourers.

The diseased tree should be cut down, the stump dug out, and the roots followed up and removed as completely as possible.

One planter gets out the fragments with a builders' sieve, and has had unusual success with his supply plants. It is convenient for the labourers to have baskets handy into which the small roots can be thrown as they are dug out, otherwise they are in danger of being scattered.

The diseased material should be destroyed by fire, preferably on the spot. It has been formerly stated that the whole tree should be cut up and burned, but I have recently satisfied myself that the necessity for this, which has often been a real difficulty to planters trying to follow instructions, may be avoided. It is easy to see how far the fungus has reached, and if the stem be cut above this point, and the top be disposed of in such a way that it can dry out, it will not develop Rosellinia. This has been verified on trees thrown into the edge of the forest, provided they did not rest upon the ground, and on others perched on large stumps and on rocks. It is better to dispose of even the stump in some such way than simply to leave it lying about as is too frequently done, but all material actually infested certainly ought to be burned. No material, root or stem, infested or uninfested, should be left lying on the ground. In one instance the stem of a cacao tree, some 5 feet long, which had been charred and thrown aside in the grass was found sheeted from end to end with conidial fructifications, and stems and branches of dead lime trees have been frequently seen, where they have rested for some distance on or close to the ground, in a similar condition. Had they been wedged among the branches of a tree they would have been quite harmless.

Under some conditions it may be necessary to choose a convenient situation and carry to it the material to be burned, but such transportation has obvious dangers in the way of scattering bits of diseased material. It should certainly be preceded by the scorching of any spore-bearing surfaces. A kerosene blow-lamp is a useful appliance in connexion with this scorching, and in starting fires.

TREATMENT OF THE SOIL. Attempts have naturally been made to arrest the progress of the disease in the soil, or to sterilize situations from which diseased trees have been removed, by the application of disinfectants to the soil. In cacao plantations in these islands lime has been frequently used, and, in Grenada especially, iron sulphate. One planter at least has used sulphur. So many factors are involved, and the circumstances are so variable that one cannot say what the actual effect of these applications has been.

Fawcett (1915) has experimented with lime, sulphur, chloronaphtholeum, copper sulphate, potassium permanganate, and potassium bisulphite. Plots which received in the one case lime and in the other sulphur at the rate of 500 grams per square metre showed no losses in three years, as compared with 6 per cent. of loss in a check plot, and 3 per cent. in a plot receiving about one-fourth the amount of sulphur, and another to which chloronaphtholeum was applied at the rate of about 50 c.c. per square metre. It was found that the last named substance was ineffective unless used in amounts involving

a prohibitive expense. Spraying the surface of the soil with copper sulphate solution equivalent to 25 grams of the salt per square metre was sufficient to check and apparently exterminate the fungus in the soil of a small diseased plot.

Bernard (1909) quotes from Raciborski a method which he regards as having been successful against root disease of tea. It consists in working up the soil with quicklime and then watering it with a 10 to 15 per cent. solution of sulphate of ammonia; the idea being that ammonia is liberated in sufficient quantity to disinfect the soil.

Bordaz (1911) has claimed very successful results in Martinique from the use of carbon bisulphide emulsion. Trials of this substance in Dominica have failed to demonstrate its usefulness against root disease, although it has given apparently good results used against soil grubs.

For my own part I cannot see that there is much scope for the use of disinfectants in the control of this disease It is safe to say that at the present time there is no disinfectant available which is cheap enough to be used in sufficient quantity to sterilize any considerable area of ground. When we are dealing with a fungus which penetrates to every part of even the thickest roots, it cannot be expected that chemical agents will kill it out, or, being necessarily of a transient nature, stop its progress, unless all woody material is removed. When this has been done, exposure of the soil to sun and air is probably just as effective as any disinfectant could be. Where it is required to deal with infested soil or accumulations of vegetable matter under shade, as for example, in the case of the lime trees with surface infections specified above, it is better to scrape away the surface soil with a hoe than merely to extinguish the fungus with a disinfectant, leaving material liable to reinfection. Such a scraping of the soil, combined with removal of low branches and of any other hindrances to the free circulation of air, has in the cases under my observation been sufficient. An application of lime, of sulphur, or according to Fawcett's results, of copper sulphate solution, would give an additional margin of safety.

The addition of lime to the soil when clearing up a spot from which infested trees have been removed is commonly practised, and is believed to contribute to success in establishing supplies. It seems to me probable that the results obtained are not so much due to the sterilizing effect of the lime as to its action in hastening the disappearance of organic matter. There is a further probability that by neutralizing soil acidity lime produces conditions less suitable to the survival of the fungus.

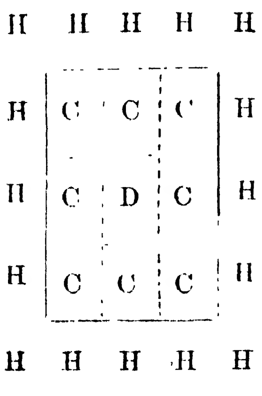
If the view here taken of the function of lime is the correct one, the main effect may be obtained by the use of slaked lime, which is the only form that can be conveniently obtained in some islands. Quicklime, because of its additional sterilizing effect, is to be preferred when equally available.

Where sulphur has to be imported, its price will not enable it to compete with lime, but there would appear to be possibilities in some places of obtaining it cheaply from local sources. Sulphur has a more definite fungicidal action than lime, and one

which may be expected to develop slowly and have considerable persistence. In this connexion Fawcett (1915) reports an experiment in which a trench 4 × 4 inches was filled with soil mixed with sulphur, using about 15 grams of sulphur to each metre of trench. The fungus travelled through the soil to the edge of this barrier, but did not pass to the plants on the other side. A part of the trench which received no sulphur was crossed by the fungus.

The effect of sulphur on the soil reaction is to increase acidity, and from this point of view it is desirable to accompany or follow its application with an application of lime.

ISOLATION OF CONTACTS.* The diseased tree having been removed, it is necessary to take steps to prevent the spread of the disease among the trees around. In a regular field, with ordinary distances of planting, the roots of the trees form a continuous system of contacts, interrupted only by the deep drains. By the time a tree is so far diseased as to be noticeable, the probabilities are great that the roots of one or more of the neighbouring trees have also become infected. It is required to cut the connexion between the infested roots and those of the surrounding healthy trees, and to break the continuity of the possibly infested surface soil. To be reasonably sure of doing this, it is necessary to carry an isolation trench outside the trees in contact with the one diseased. Thus, in an undrained field, if D in the first diagram (1) represents a diseased tree, C the possible contacts, and H the healthy trees, the isolation trench should take the course indicated by the unbroken line, and will include nine trees.



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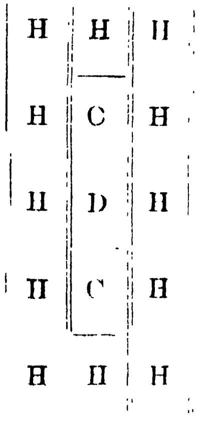

II.

Neither the roots of the trees nor the course of the disease follow regular lines, and it is quite improbable that all the eight contacts are infected, but there is no practicable means of knowing which remain free. In order to save those which are

* This section, with minor alterations, is reprinted from the author's pamphlet on diseases of lime trees. (No. 79, Imperial Department of Agriculture.)

still uninfected, it is advisable to cut up the enclosed area chess-board fashion as indicated by the dotted lines. If these secondary trenches are omitted, it is likely that the contacts will all go off sooner or later in the manner already described.

In situations where there is a risk of soil infections the trees still further out, (H...H in the diagrams), should have some special attention, especially if D is an advanced case when discovered.

One lime planter in Dominica has anticipated events and has separated his trees throughout by trenches in both directions, so that each stands in a square plot cut off from the rest. This measure is regarded by the owner, and by Mr. G. A. Jones, who has reported on it from time to time, as having completely changed the prospects of the estate. Whereas the losses from root disease were becoming increasingly serious and were quite out of control, they are now reduced to occasional sporadic cases which cause no apprehension.

While few planters will be disposed to go so far as this except under pressure of heavy losses, there is much to be said for the general adoption of the system represented in the second diagram (II), where a permanent drain (denoted by a double line) exists between every row and the next. All that is required for isolation is the cutting of cross trenches between C and H, to separate contacts from healthy trees, and secondary cross trenches between D and C, to save the contacts if they do not prove to have become infected. The length of isolation trench required is reduced to one-sixth. It will be objected that the provision of the drains in the first instance involves much more expense, but apart from such purely agricultural benefits as may be obtained, the difference is a very practical one between cutting trenches in a systematic way, and at a convenient time, on the one hand, and on the other hand having to do it as an emergency measure, it may be at a time when it is highly inconvenient. It may be suggested that the expense of draining should be discounted by regarding it as a system of insurance, whereby from each sporadic case of disease which occurs, two trees only, instead of eight, are exposed to root infection. The adoption of such a system would prevent the development of the large open spaces, extending sometimes over the sites of dozens of trees, which are the most disquieting feature of clearings where this disease has become well established. There are arguments for this type of draining as a purely agricultural measure in wet districts, and there are instances in Dominica of its adoption on such grounds alone. The most serious objection I have heard urged against close draining in lime fields concerns the inconvenience and loss experienced in the collection of the crop, but I doubt if this comes near to balancing the advantages of the system. On steep slopes, of course, the trenching will have to be carried out with due regard to contours and the danger of slips and of wash; on all recent clearings there will be breaks due to large stumps. There are some situations where the method is quite out of the question, but they afford no argument against applying it where difficulties are non-existent, or can be overcome. Like the preventive measures already indicated, it should be applied first of all in the

situations where the losses are greatest, and extended as opportunity permits.

It is not necessary, from the point of view of root disease that the trenches should conduct water; indeed, where loss of surface soil by wash is feared more than the alternate danger of water-logging, it may be advisable deliberately to check their function in this respect. They may then be periodically cleaned out, and the deposit returned to the soil. It gives a clearer point of view if the system is regarded as one of permanent isolation trenches with a secondary function as drains, rather than as one of drains in the first instance.

Returning to consideration of the treatment of infested spots, there are two commonly existing situations which need to be dealt with. These are (1) the case where a large patch of trees has already been eaten out of a field, and the disease is spreading outward around its circumference, and (2) the case where one or more trees have been attacked around a large forest stump, infested or likely to become so, which together with its heavy roots prevents the cutting of trenches over an area which may include quite a number of trees. In both cases the procedure has to be modified to suit each individual set of circumstances, but still follows the simple principles set out above. Where roughly parallel main drains or watercourses exist on each side of the area, they should be joined across above and below to establish an outward limit, even though it may be a wide one, to the spread of the infection. Then working inward from this, successive trees or rows of trees which appear healthy may be separated off wherever it is possible to dig a trench, and the disease thus confined to the narrowest limits.

In the situations, sometimes met with, especially in cacao plantations, where the trees are growing amongst a confusion of fallen rocks, the possible measures are limited to early removal of so much of an infested tree as can be got at, and the liming of the soil about adjacent trees, with a view to preventing spore infections of the material which accumulates in the enclosed pockets of soil.

It has been commonly recommended that a trench be carried in a circle around diseased trees and their contacts. This method has practical disadvantages. The extent of the existing infection can never be ascertained by inspection, and a wide circle, while enclosing many healthy trees, may prove too narrow to include some line of infection that has run off in advance of the general spread. A circle leads nowhere, whereas a system of squares may be added to at any point and be carried in any direction, and is capable of any subdivision. It has moreover the great advantage of linking up with an existing or prospective drainage system.

As regards the form of the trench itself, there is but one essential so far as root disease is concerned: that it should be deep enough to cut through all the roots passing across its situation. When digging near an infected tree, the earth removed should be thrown inward as a precaution against the scattering of possibly diseased material among the healthy trees. This

refers more particularly to secondary trenches; the outer trench should be put far enough away to avoid, in general, the chance of finding such material. The earth should be distributed, not banked at the edge of the trench, unless put there in exceptional circumstances with the express purpose of avoiding wash. Under no circumstances, however, should the collar of the tree be earthed up. Roots passing into the healthy area should be followed up and removed, so far as this can be done without much injury to other roots. It would be well if cut ends of roots were painted.

SURVIVAL OF SUPPLY PLANTS. On the thoroughness with which the clearing-up is done depends the chance of survival of an early supply plant. It has been found in St. Lucia, where the results of several years of experience of the treatment of this disease on cacao are now available, that where the work has been carried out under the personal supervision of the planter, supplies put in a month afterwards have remained healthy. The longer the delay the greater the chance of survival. It must be remembered that a supply may do well for a few months while its roots occupy the site from which the stump was removed, and then become infected from some outlying fragment of the old tree as its roots spread wider. Such cases have been definitely traced.

THE POSSIBILITIES OF CONTROL.

Rosellinia disease in orchard cultivations is by its nature capable of the most serious consequences It is cumulative in its effects: each tree that contracts it infects as a rule not merely one but several more, and each tree killed takes at least five or six years to replace. In new clearings, encumbered with stumps and logs, and in cacao fields with large shade trees, the disease is difficult to deal with.

It may be confidently claimed, however, that the application of the principles of prevention and control set out in the preceding pages will reduce the annual losses to a minimum that is not likely to be serious, and one may further expect a gradual diminution year by year of even the sporadic cases

Control does not depend on any special apparatus or material, but on operations of a familiar type, demanding little special skill. Everything depends on the vigilance and thoroughness with which they are carried out. Careless or half-hearted work is of little use against this disease, which is apt to pursue its course with an appearance of deliberation and inevitability which is disconcerting.

SUMMARY.

Several species of the genus Rosellinia give rise to a well-defined type of root disease in numerous countries of the world, temperate and tropical. The fungus kills out cultivated trees or shrubs in patches, and often infests the soil and destroys practically all vegetation with which it comes into contact.

In the Lesser Antilles, Rosellinia diseases occur in Guadeloupe, Dominica, Martinique, St. Lucia, St. Vincent, and Grenada; they are unknown in the remaining islands of the group, which have drier climates.

The range of hosts is an exceedingly wide one, embracing practically all the important cultivated and semi-cultivated plants, but the cultivations most affected are those of cacao (in all the islands), coffee (in Guadeloupe and Martinique), limes (on new clearings in Dominica), and arrowroot (in the interior districts of St Vincent).

The disease on cacao is usually caused by the species *Rosellinia Pepo*, and in most cases at the present time, the fields being well established, is communicated from the roots of dead or dying shade trees, especially breadfruit, avocado pear, and pois-doux. Another species, as yet unidentified, is believed to attack cacao in certain localities.

The disease on limes and coffee is caused by *R. Pepo* or *R. bunodes*, indifferently.

The first cases in new clearings are usually associated with forest stumps left to decay, especially those of certain special trees. Subsequent cases arise from the spread of the fungus from tree to tree along the roots, or by infection from surface soil rich in decaying vegetable matter, which readily becomes infested in damp and shaded situations.

An infested tree may be killed gradually by the progressive investment of the roots, or rather quickly by the destruction of the bark around the collar. The fungus penetrates both bark and wood. Conidia are produced with great readiness wherever the mycelium emerges into the open; perithecia occur later, and especially in the case of *R. Pepo* their formation may be long delayed.

Much can be done to prevent outbreaks of the disease by measures directed towards exposing to wind and sun the soil, the bases of the trees, and any logs or other dead material lying about. Cases which arise may be restricted by these measures and by the provision of a close system of trenches to prevent root contact.

Treatment by excision and exposure is successful in the early stages of infection, but in practice these are hardly ever detected. Periodical surveys would save many trees.

Infested trees should be flamed and then promptly removed, all roots dug out and burnt, the soil limed, and the situation exposed as much as possible. All adjacent trees should be isolated from each other by trenches.

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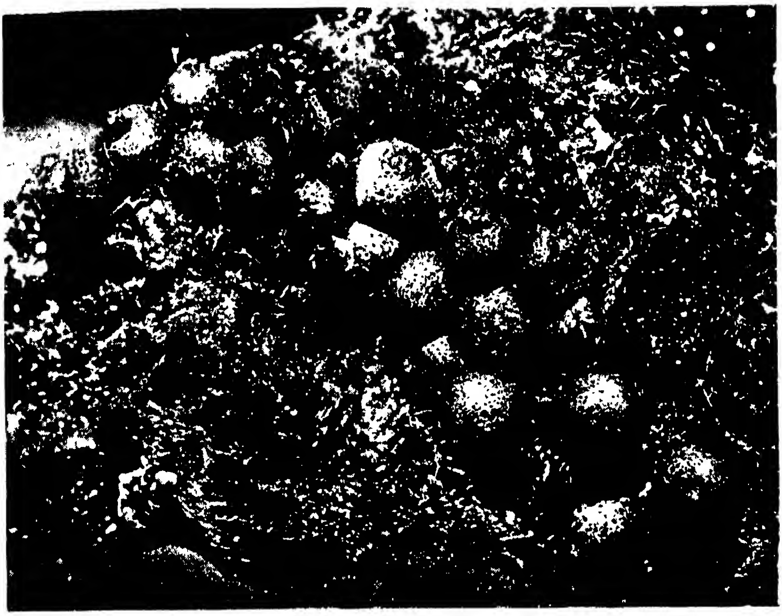

Fig. 1

ROSELLINIA (A) PERITHECIA × 3½

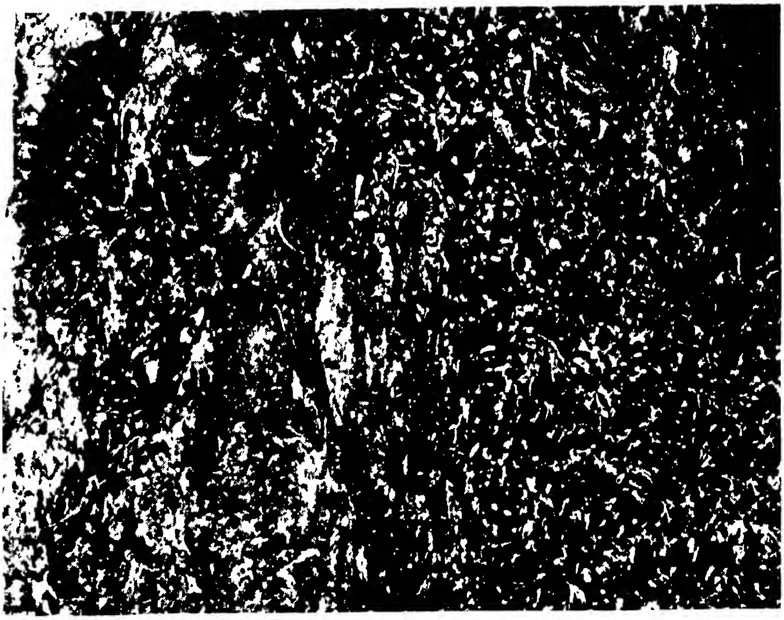

Fig. 2.

ROSELLINIA (A) CONIDIAL FRUCTIFICATIONS. × 1½

Fig. 3.
ROSELLINIA (A) WHITE MYCELIUM UNDER BARK Nat size

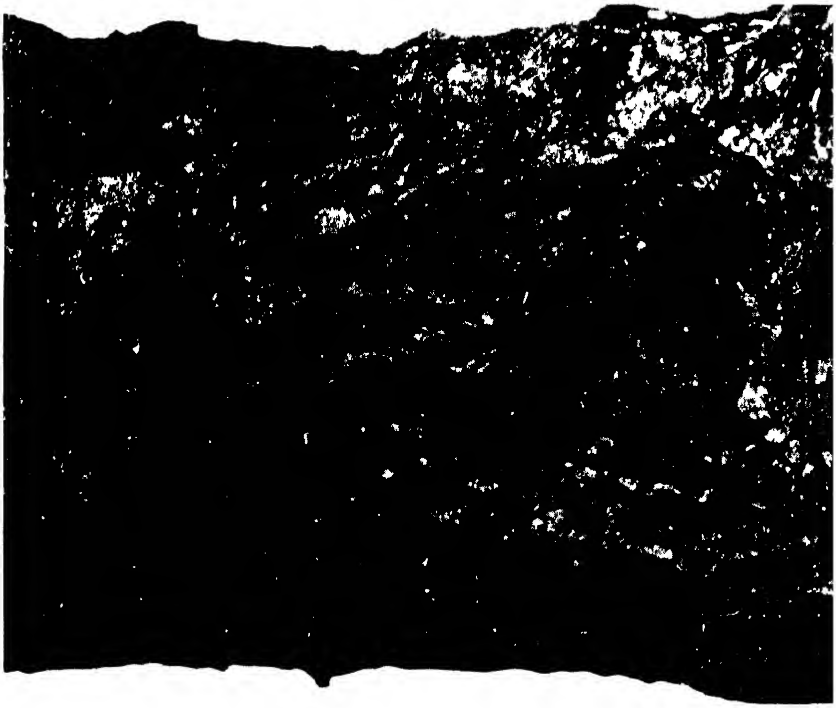

Fig. 4.
ROSELLINIA (A) SMOKY MYCELIUM ON SURFACE OF BARK
× 1½.

Fig. 5

ROSELLINIA (A). EARLY STAGE OF INFECTION ON ROOT.
Nat. size.

Fig. 6

ROSELLINIA BUNODES. MYCELIAL STRANDS IN BARK OF LIME
× 1½.

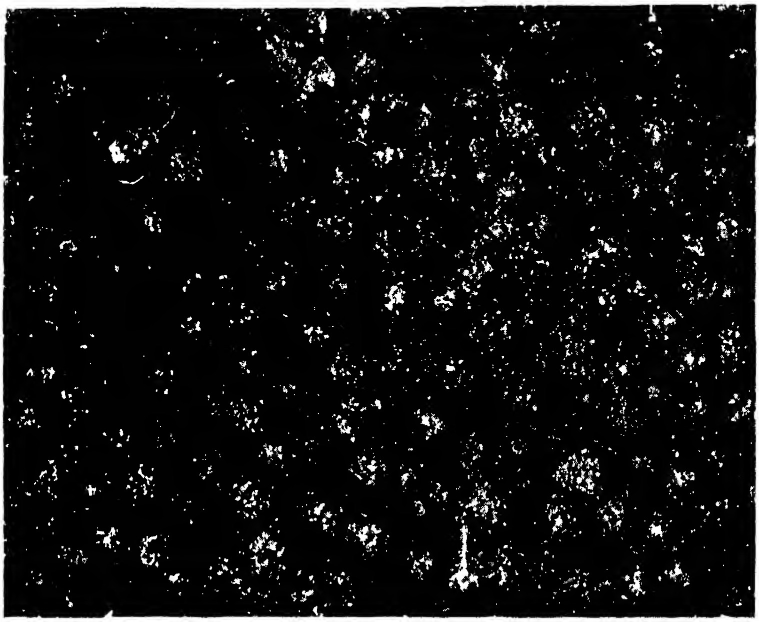

Fig. 7.
ROSELLINIA BUNODES PERITHECIA × 1.

Fig. 8
ROSELLINIA BUNODES: CONIDIAL FRUCTIFICATIONS. × 1½.

Fig. 9.
ROSELLINIA BUNODES: MYCELIAL STRANDS IN LIME WOOD.
× 2. (Longitudinal section.)

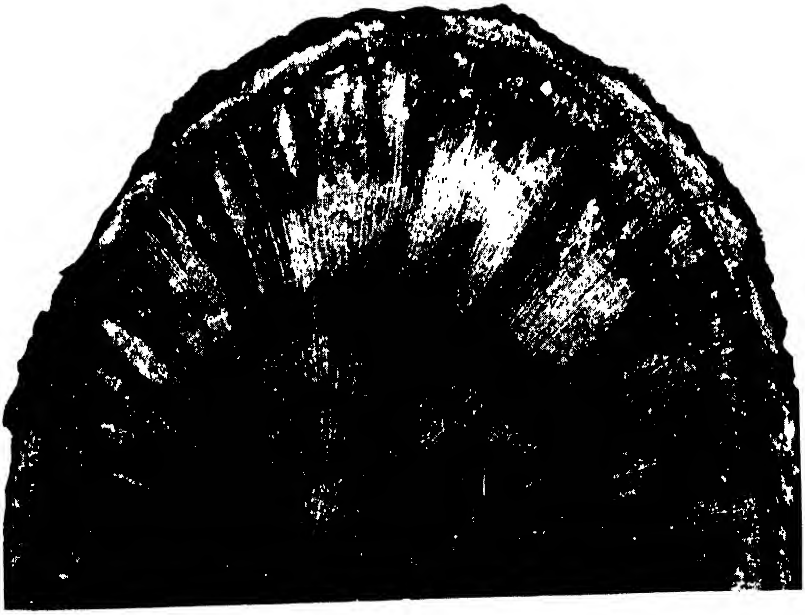

Fig. 10.
ROSELLINIA BUNODES: MYCELIAL STRANDS IN LIME WOOD.
× 1½. (Trans. section.)

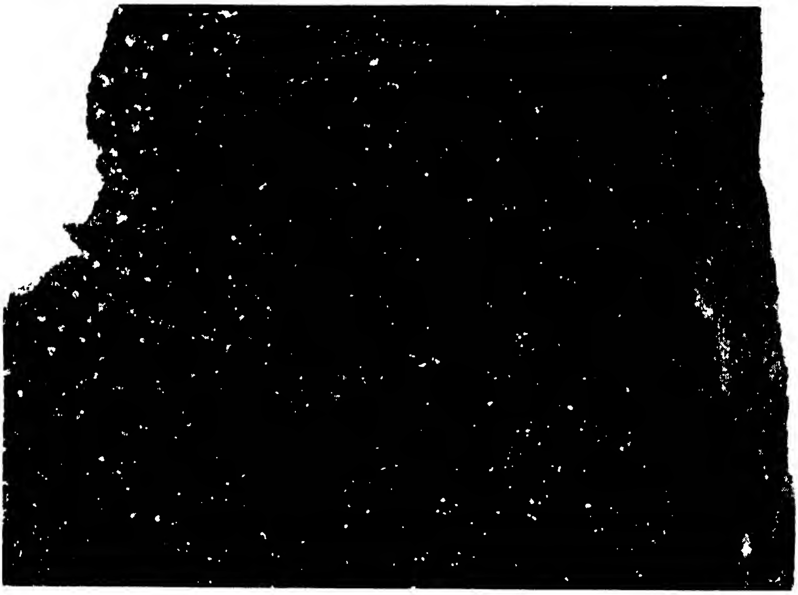

Fig. 11

ROSELLINIA (C PERITHECIA × 3

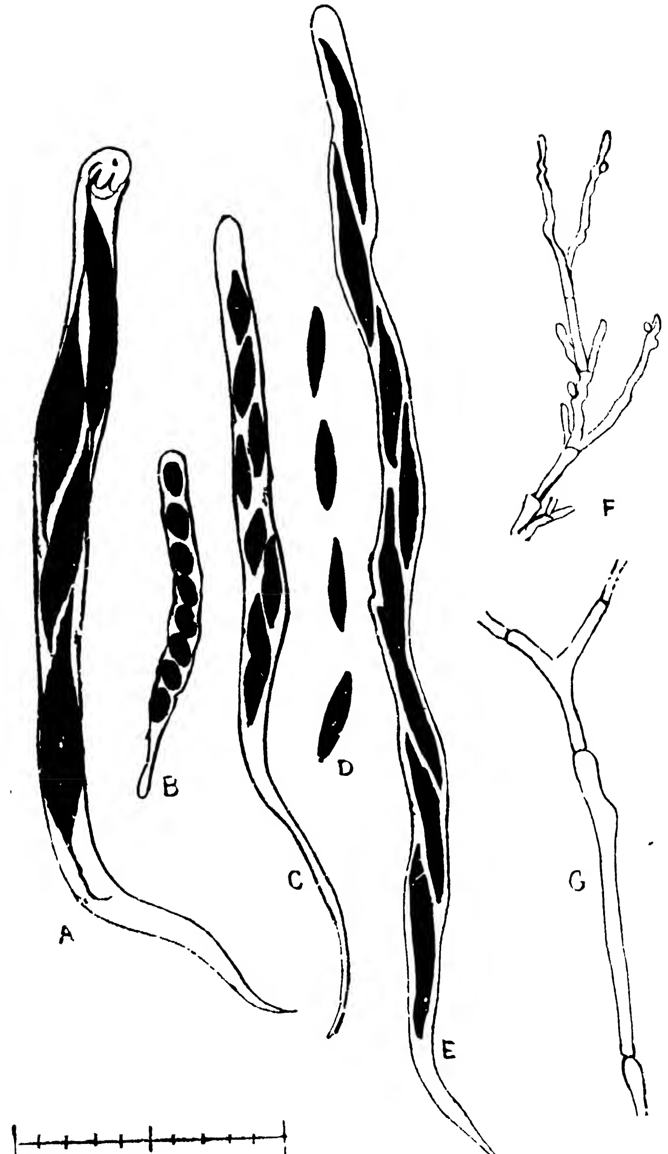

Fig. 12.

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EXPLANATION OF FIGURES.

1. *Rosellinia Pepo* : perithecia on cacao.
2. „ „ : conidial fructifications on cacao wood.
3. „ „ : white mycelium under bark of cacao.
4. „ „ : smoky mycelium on bark of cacao stem.
5. „ „ : early stage of infection on living cacao root: (bark removed).
6. *R. bunodes* : mycelium, on, in, and beneath bark of lime.
7. „ : perithecia on lime bark.
8. „ : conidial fructifications (with a few perithecia) on a lime twig.
9. „ : mycelial strands in lime wood (long. sect.)
10. „ : the same (trans. sect.)
11. Unidentified species (C): perithecia on cacao wood.
12. A. Ascus of *R. bunodes*. B. Ascus of *R. subiculata*. C.* Ascus of the unidentified species (Fig. 11). D. Spores of supposed *R. bothrina*. E. Ascus of *R. Pepo*. F. Terminal hypha from conidial fructifications of *R. Pepo*. G. External hypha characteristic of Rosellinia spp.

*In Fig. 12 C. the engraver has somewhat reduced the length of the spores first, third, and fifth from the apex of the ascus. The spores of this species are very similar to those of D.

THE SHEDDING OF FLOWER-BUDS IN COTTON.

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The shedding of flower buds in cotton has been noted by Balls (1) in Egypt, and by Thornton (2) in Southern Nigeria. Balls mentions a strain derived from an Egypto-American cross, some plants of which shed their buds just before opening them, while their neighbours retained them. Thornton alludes to the shedding of buds of about $\frac{1}{4}$-inch in diameter, and attributes it to unfavourable climatic conditions.

So far bud-shedding does not appear to have received much attention in the West Indies, although casual allusion to it has been made in various publications. It exists, however, in a varying degree, in all the varieties of cotton which the writer has examined.

The statement has been made that if West Indian native cottons be sown 'out of season' they will refuse to flower until their proper flowering time, i.e. November to May. It was in testing the truth of this statement that the question of bud-shedding received attention from the writer.

In St. Vincent the majority of buds shed are from 2-5 mm. in diameter, but occasionally buds up to 8 mm. in diameter may be shed. Shedding leads to sterility, which is either partial or complete.

It will be convenient at this point to describe the behaviour of certain types of cotton planted on December 5.

ST. VINCENT NATIVE TYPE A.

This cotton in nine months grew to a height of over 8 feet. The plants were examined frequently and the first flower-bud, which, however, dropped when 2 mm. in diameter, was seen on February 8. Since then the plant has continued to produce flower buds which have all dropped in the same way. The appearance of the plants is peculiar. There is a stout central axis of about 8 feet in height. From the lower 3 feet of the stem spring numerous monopodial branches, which grow outward and then upward, finally becoming almost parallel with the main stem. Above the region of monopodia, every extra-axillary bud gives rise to a sympodium of from 12 to 18 inches in length, on which are seen scars, marking the site of dropped buds. At the extreme tip of the sympodium can be seen a minute flower bud, often yellowish-green in colour, having almost completely severed its connexion with the parent branch. No less than 375 scars were counted on one of these plants. The parent tree has been examined from time to time, and such sympodia as are present on it are showing the same features. There is this difference between the parent tree and the progeny: in the former numer-

(1) W. L. Balls: *The Cotton Plant in Egypt*, p. 64.
(2) T. Thornton: *Proceedings of the International Congress of Tropical Agriculture*, 1914.

ous monopodia are springing from the base of the plant which again bear monopodia, whereas in the latter, the monopodia are bearing sympodia as in the main stem. One may confidently expect that later in the year, the habit of bud-shedding will cease more or less abruptly and that normal flowering will commence.

ST. VINCENT NATIVE TYPE B.

In the case of this cotton, certain modification occurs. From the lower part of the stem spring monopodia from the extra-axillary buds. Higher up the extra-axillary buds produce sympodia. Sympodia are also produced from the monopodia. A few flowers were produced about three months after sowing, the maximum number of flowers for any one plant being three. After this the habit of bud-shedding set in, lasting for about eight weeks. Later it was noticed that the plants had ceased producing sympodia and were now producing only monopodia, both from the main stem and from the primary monopodia. No more flowers have been produced to the date of writing (September 11), although at this date sympodia have begun to arise from extra-axillary buds at the top of the main stem, and these sympodia exhibit bud-shedding of the same type as those produced first.

ST. VINCENT NATIVE TYPE C.

This cotton is of the Kidney type (*G. brasiliense* var.). A certain number of flowers were produced, beginning ten and a half weeks from planting. The maximum number of flowers for any one plant was twenty-four. Subsequently the formation of further flowers was prevented for a period of eight weeks by bud-dropping. The plants were then ratooned, so that further observations could not be carried out.

These three cottons form a graded series. We now have to consider the behaviour of a native cotton from St. Croix.

ST. CROIX NATIVE TYPE 1.

A plot of this cotton was planted at the end of August. There was no sign of bud-shedding. Flowering commenced about eleven weeks after sowing and continued till the beginning of June when the bud-shedding habit set in gradually. By the end of June no flowers were being produced, although flower-buds were present abundantly on the sympodia It was noticed, however, that in the case of plants which were cut back close to the ground, the young shoots grew very vigorously, but instead of producing sympodia they produced only monopodia. The bud-dropping habit in the unpruned plants is now (September 11) showing signs of coming to an end, since most of the flower-buds are developing normally.

A further sowing was made on May 11. After eleven weeks flower-buds were looked for but none were found, and it was seen that the plants were producing only monopodia. This type, like the St. Vincent Native Type B, evidently has the power of regulating flower production in more than one way.

The Cauto cotton of Cuba (*G. brasiliense*, var. *apospermum*, Sprague) seems to behave similarly. Sown at the end of August, flowering commenced in ten weeks and continued till the end of June. Unfortunately, the plants had to be ratooned close to the ground so that no opportunity has occurred of examining the behaviour of unpruned plants. It is noticeable, however, that in the new shoots, no sympodia have yet been produced. The plot planted on May 11 has produced abundant monopodia, but no sympodia to the date of writing (September 11).

SEREDO COTTONS FROM BRAZIL.

These are perennial types of unknown hybrid origin. The bud-shedding habit is markedly developed. Some of the plants have been under observation for eighteen months. Broadly speaking flowering takes place in from eleven to twelve weeks when planted in August or September, and continues till the middle of June. After that, bud-shedding causes the production of flowers to cease totally. In August, signs that the period of bud-shedding is drawing to a close begin to be apparent, and scattered flowers are found towards the end of that month. The bud-shedding habit is thrown off very gradually, and it is not till the end of September that full flowering is resumed.

SEA ISLAND AND AMERICAN UPLAND.

When we come to examine Sea Island and American Upland cottons, the phenomena are totally different. Careful search in plots of such cottons planted on May 11, has shown that a certain amount of bud-dropping does exist in Sea Island cotton, and may in certain cases retard the flowering period for three or four weeks. In no case has cessation of flowering approaching the sterility already described been noticed. The maximum number of buds shed by a single plant has not exceeded twenty-five. Taking a single row of cotton planted 5 feet × 18 inches, the number of buds dropped after nine weeks of growth averaged twelve (on twenty-five plants). This shows that bud-dropping is one of the factors which influence yield in St. Vincent. Further observation is necessary, as the question is obviously an important one in connexion with manurial experiments.

In the only variety (Southern Cross) of American Upland under observation, bud-shedding is extremely rare.

PROVISIONAL CLASSIFICATION OF TYPES.

It is clear from what has been said, that in the West Indian native cottons described, and also in the Brazilian Seredo cottons, there is a definite periodicity in flowering, which is due in some cases to the substitution of monopodia for sympodia, and in others to the habit of shedding flower buds when a few millimeters in diameter. During the period September to June, flowering takes place freely with little or no shedding of buds, but from June to September there is complete cessation of flowering.

It appears that the root conditions have little to do with the habit, since plants growing in tubs, where the water-supply

could be controlled were affected at approximately the same time, and in precisely the same way as those in the open ground.

That the bud-shedding habit is not influenced to any extent by climate is shown by the fact that the native cottons of the Southern Grenadines, where rainfall is much less than in St. Vincent, were found in August to be as subject to the habit as in the latter island.

In regard to Sea Island and Upland cottons, bud-shedding interferes but little with the time of flowering. Sea Island invariably flowers in about eight weeks after sowing, and Upland in from six to seven weeks, whatever the season may be.

Broadly then, a separation of types may be made as follows:—

(a) Cottons exhibiting no periodicity in flowering such as Sea Island and Upland.

(b) Cottons exhibiting periodicity in a varying degree, comprising many West Indian Natives and the Seredo cottons from Brazil.

The bud-shedding in Sea Island cotton is not in the same order of phenomena as that in the Native types. It is probably influenced by many factors, chief among which are rapid changes in weather conditions and, in particular, of over-humidity of the atmosphere.

A further subdivision of types may be made as follows:—

0—Types which have no periodicity in flowering.
1—Types such as St. Vincent Native C, which produce a certain number of flowers and then cease.
2—Types such as St. Vincent Native B, which produce a less number of flowers than class 1.
3—Types such as St. Vincent Native A, which exhibit complete cessation of flowering from June to October.

This classification does not imply that old plants will necessarily behave in the same manner as their progeny when sown out of season. It has already been explained that there is a tendency for older plants to limit themselves solely to the production of monopodia, in the interval between one flowering season and the next.

To determine the particular class of any plant it would be necessary to sow it out of season, say, from December to February, and observe its behaviour.

HEREDITY OF TENDENCY TO SHED FLOWER-BUDS.

Work on this subject has not proceeded far as yet. Certain conclusions have been reached, however, in regard to the first hybrid generation, which it is advisable to place on record.

Experiment 1. Sea Island (o) × St. Croix Native Type 1 (2).

The first flower appeared in seventy-one days after planting, and all the plants (eight in number) produced flowers before the seventy-sixth day. It was noticed at this time that many of the younger sympodia were shedding their flower-buds in just the same manner as has been described in St. Vincent Native A.

After each plant had produced some five or six flowers, the habit of shedding the buds set in and the plants showed no signs of normal flowering till August. Towards the middle of August it was seen that fewer buds were dropping and that many buds were developing normally. On August 26, one of the plants flowered, followed in rapid succession by the others. By the middle of September, flowering seemed to be almost normal.

Planted on May 11, a plot of this hybrid produced flower-buds in abundance but no flowers. At the beginning of September, the plants (fifty-one in number) were showing normal buds.

In this hybrid therefore, the habit of shedding buds behaves as a dominant.

Experiment 2. Sea Island (o) × Seredo Type 1 (2).

Flower-buds were seen in nine weeks after sowing (March 1), but during the following six months no flowers were formed. At the beginning of September, normal flower-buds appeared, the number of buds shed decreasing greatly.

The habit of shedding buds is therefore dominant.

Experiment 3. Seredo Type 2 (2) × St. Croix Native (2).

The behaviour of this type resembled that of the St. Croix Native parent in that no sympodia appeared, but only monopodia, during five months from the sowing date (May 11).

Experiment 4. Cauto (*G. Brasiliense*, var. *apospermum*, Sprague) (1) × Upland (o).

The F/1 resembled the Upland parent, flowering in sixty-eight days. Cauto planted at the same time produced only monopodia.

Experiment 5. Upland (o) × St. Croix Native (2).

The behaviour of this hybrid is peculiar. When planted in a situation where the soil was deep and well drained, the plants behaved almost like the Upland parent. Little shedding of buds occurred, and flowering took place in eight weeks from sowing (May 11). In another place where the soil was rather shallow and badly drained, the plants shed the first formed buds and delayed the date of the first flower twenty one days. After this, flowers were produced normally. The shedding of buds in this hybrid is to be attributed to unfavourable climatic and soil conditions rather than to any tendency towards periodicity in flowering,

The habit of shedding buds behaves here as a recessive and not as a dominant.

CORRELATION OF PERIODICITY IN FLOWERING WITH RESISTANCE TO LEAF-BLISTER MITE (*Eriophyes gossypii*, BANKS).

In a paper,* appearing in another part of this Journal, the present writer points out that West Indian Native cottons can be

* Note on Resistance to Cotton Leaf-Blister Mite (*Eriophyes gossypii* Banks), with special reference to Budded cottons, and to cotton Hybrids.

separated into: (a) types immune to leaf-blister mite, (b) types which acquire leaf-blister mite but which may be classified as fairly resistant in comparison with the very susceptible Sea Island.

In general it may be said that the nearer an indigenous cotton approaches Sea Island in morphological characters, the more susceptible it becomes to leaf-blister mite. A similar statement can be made for that type of periodicity in flowering due to bud-shedding, i.e. the more extreme the periodicity in flowering becomes, the greater the divergence from the morphological characters of Sea Island, and the greater resistance to leaf-blister mite.

St. Vincent Natives A and B, the Seredo cottons from Brazil, and St. Croix Native are all immune to leaf-blister mite, and all exhibit bud-shedding of classes 3 or 2. St. Vincent Native Type C belongs to the Kidney series, i.e., is a variety of *Gossypium brasiliense*. It shows an approach to Sea Island in (a) the pitted dark-green bolls, (b) in the glabrous petioles, (c) in the general characters of bracts, calyx, corolla, and stamens. It shows partial resistance to leaf-blister mite, and exhibits bud-shedding of class 1.

Now in a hybrid between a West Indian Native immune to leaf-blister mite and the susceptible Sea Island, we find that in the F/1 almost complete resistance is developed, and at the same time the habit of shedding buds is in evidence.

When Upland, which is susceptible to leaf-blister mite, is crossed with an immune West Indian Native which also exhibits periodicity in flowering of class 2 or 3, the F/1 is, so far as one can judge, almost as susceptible to leaf-blister mite as its Upland parent, while periodicity in flowering of class O is shown.

Further, in the F/2 of a cross between Sea Island and West Indian Native, types immune to leaf-blister mite have appeared, and these plants all have the bud-shedding habit of class 2 or 3.

There is evidently a correlation between resistance to leaf-blister mite and periodicity in flowering.

Further work will show whether correlation is complete or partial.

SUMMARY.

1. It has been shown that certain cottons—the West Indian Natives and Seredo cottons from Brazil, exhibit periodicity in flowering. They do not, as a rule, produce flowers during an ill-defined period from June to September. Flower production ceases either because monopodial branching is substituted for sympodial, or because the flower-buds are shed when from 2-5 mm. in diameter. Other types such as Upland and Sea Island have no periodicity of this kind.

2. Flower-bud shedding is not influenced greatly by root conditions or rainfall, since plants growing in tubs, where water-supply could be controlled, developed the habit at the same time as those in the open ground. In other islands where climatic

conditions are much different, the same features were seen as in St. Vincent.

3. In hybrids between types differing in the bud-shedding habit, it has been established that when Sea Island is crossed with a West Indian Native in which the bud-shedding habit is developed, the F/1 exhibits this bud-shedding.

The presence of the habit in this cross is thus dominant to its absence.

4. Crosses between Upland and West Indian Native give rise to an F/1 which does not shed its buds.

The absence of the habit in this cross is thus dominant to its presence.

5. A correlation is suggested between resistance to cotton leaf-blister mite (*Eriophyes gossypii*, Banks) and periodicity in flowering.

NOTES ON RESISTANCE TO COTTON LEAF BLISTER MITE WITH SPECIAL REFERENCE TO BUDDED COTTONS, AND TO COTTON HYBRIDS.

BY S. C. HARLAND, B.SC. (LOND.),

Assistant Agricultural Superintendent, St. Vincent.

INTRODUCTION.

The leaf-blister mite of cotton, *Eriophyes gossypii*, Banks, is well known as a pest of that plant in the West Indies. The following general description of it is given by Ballou (1):—

'The leaf-blister mite attacks all parts of the cotton plant except the roots. The blisters which are characteristic of this mite are distortions or swellings, which result from its presence, and are probably due to an irritation in the tissues of the plant caused by its feeding. They are lined with a thick growth of very fine hairs, among which the mites live. The leaf-blister mite is almost microscopic in size. It is so small that even when very abundant the individual mites can scarcely be seen even with the aid of a good magnifying glass.'

VARIETAL RESISTANCE.

The resisting power of different varieties of cotton to the mite, varies greatly. All gradations exist between great susceptibility and complete immunity. Classification of the various types is thus rendered very difficult. The following table subdivides those cottons which have been under observation into (1) attacked, (2) immune.

VARIETIES ATTACKED.	VARIETIES IMMUNE.
Sea Island	Five different varieties of Seredo cotton from Brazil.
Egyptian (Sakel)	Four natives from St. Croix.
American Upland (Southern Cross)	A native cotton from St. Thomas.
Caravonica	" " " from Tortola.
Chinese (*G. Nanking*, Meyen)	" " " from Dominica
Hawaiian (*G. Tomentosum*, Watt)	Eight natives from St. Vincent.
A Virgin Gorda Native	Five natives from Southern Grenadines.
Four natives from Southern Grenadines	
Three St. Vincent natives	
Cauto (*G. brasiliense*, var. *apospermum*, Sprague)	

Of the varieties which are attacked, Sea Island and Egyptian appear to be most susceptible, followed by Upland and Caravonica. Observations on the Chinese and Hawaiian varieties have not been sufficiently extensive to define exactly their behaviour towards the mite. They have been seen with a fair number of galls. The non-immune native cottons including Cauto, which is supposed to be indigenous to Cuba, are comparatively resistant, and, broadly speaking, they do not acquire leaf-blister mite so quickly as Sea Island, and their growth is seldom seriously affected.

Correlation of Resistance to Leaf-blister Mite with Morphological Characters.

The question of the correlation of morphological characters with resistance is an interesting one. Those varieties that are immune all agree in possessing a predominantly three-lobed leaf and a smooth boll, i.e. a boll in which the glands are situated more or less below the surface. Furthermore they are all perennial types. In regard to the non-immune native types, they are found to agree in the possession of a leaf which is five-, occasionally seven-lobed, and a boll which resembles that of Sea Island or Egyptian in that the glands are at or near the surface, consequently imparting to the bolls a more or less pitted appearance. All the other non-immune types listed, have pitted bolls, but not all have the five- or seven-lobed leaf. It is doubtful, however, whether the fairly general correlation outlined above is at all a universal one

Resistance in Budded Cottons.

The West Indian immune types are exceedingly vigorous and hardy. Attempts have been made therefore to see whether the immunity to blister mite, together with the native ability to withstand unfavourable conditions, can be transferred to Sea Island cotton when the latter is budded on to the former. Experiments in budding other varieties have also been carried out. The results, so far as they concern resistance to leaf-blister mite are placed below.

No. of Experiment.	Stock.	Scion.	Resistance of Scion when budded.
1	Seredo, Type 1 (I)	Sea Island (S)	Apparently increased.
2	Sea Island (S)	Seredo, Type 1 (I)	Immune.
3	Seredo, Type 11 (I)	Sea Island (S)	Apparently increased.
4	Seredo, Type 111 (I)	Sea Island (S)	Apparently increased.
5	Seredo, Type 111 (I)	Upland (S)	Apparently increased.
6	Sea Island (S)	Bequia Native (F.R)	Fairly resistant
7	Bequia Native (F.R.)	Upland (S)	Susceptible.
8	St. Croix Native Type 1 (I)	Sea Island (S)	Apparently increased.

I = Immune ; S Susceptible ; F.R. – Fairly resistant.

These results tend to show :—

(a) When the stock is susceptible and the scion is immune the scion retains its immunity.

(b) When the stock is immune and the scion is susceptible the resistance of the scion is apparently increased.

(c) When the stock is fairly resistant and the scion is susceptible, the susceptibility of the scion is unchanged.

(d) When the stock is susceptible and the scion fairly resistant, the resistance of the scion remains the same.

In Experiment 2, the Sea Island stock gave rise to several shoots after about five months' growth. These acquired leaf-blister mite badly, and the contrast with the immune branches of the scion was very marked.

In regard to the apparent increase in resistance in experiments 1, 3, 4 and 8, there is uncertainty whether the resistance is increased by the stock or whether the bud being set comparatively high up the stem, the opportunities for infection are not so great.

[Note.—The budding of cottons is a comparatively simple operation. The stock should be in a condition when the bark is easily separable. A young plant about 2 feet high makes a suitable stock. The bud, which should be taken from a branch of approximately the same size and maturity as the stock, is inserted about 12 inches from the base of the stem, and bound with ordinary tape. It is immaterial whether petioled or non-petioled budwood is used. Union takes place very quickly, and the stem may be severed above the bud after the lapse of about fourteen days.]

In the Annual Report of the Hawaiian Agricultural Experiment Station for 1910, p. 63, appears allusion to the budding of cottons. All inferior Caravonica plants were budded with selected varieties.

RESISTANCE IN HYBRID COTTONS.

The present writer has shown (²) that a cross between the immune variety St. Croix Native Type 1 and the susceptible Sea Island variety Chance, gives an F/1, which is to all intents and purposes immune, i.e. a few scattered mite galls may appear but the plant may throw off the infection completely at a later stage. In the F/2, segregation occurs, and both susceptible and immune types appear. These are connected by a series of intermediates between which no clear line of demarcation can be drawn. Data in regard to the F/1 of a further series of crosses will be found below.

No. of Experiment.	Cross.	Resistance of F/1.
1	Seredo Type 1 (I) Sea Island (S)	Almost immune.
2	Seredo Type 11 (I) Sea Island (S	Almost immune.
3	Upland (S) Sea Island (S)	Susceptible.
4	Upland (S) St. Croix Native (I)	Susceptible.
5	Upland (S) Cauto (F. R)	Susceptible.
6	Seredo Type 11 (I) St. Croix Native (I)	Almost immune.

These results tend to show :—

(a) The F/1 of the cross 'immune' by 'susceptible' is almost immune when Sea Island is the susceptible parent, but when Upland is used as the susceptible parent the F/1 is also susceptible.
(b) The F/1 of the cross 'susceptible' by 'susceptible' is susceptible.
(c) The F/1 of the cross 'susceptible' by 'fairly resistant' is susceptible.

The result of Experiment 6 is anomalous, and the experiment needs repeating. F/1 is, however, apparently not of a vigorous constitution, and this may partially explain the presence of a few mite galls.

COMPARISON OF BUDDED WITH HYBRID COTTONS.

A comparison upon which any broad generalizations could be based is inadvisable in the light of present knowledge. It

may be pointed out, however, that budding and hybridization appear to affect the resistance to leaf-blister mite in a very similar manner.

BIBLIOGRAPHY.

(1) Ballou, H. A. 'Insect Pests of the Lesser Antilles', pp. 47-8.

(2) Harland, S. C. A study of Inheritance in the Cotton Hybrid, Sea Island and Native St. Croix, in Report of the Agricultural Experiment Station in St. Croix, 1913-14, pp. 50-60.

ON THE GENETICS OF CRINKLED DWARF ROGUES IN SEA ISLAND COTTON. Part 1.

BY S. C. HARLAND, B.Sc., (LOND.),
Assistant Agricultural Superintendent, St. Vincent.

In September 1915, the writer noticed in a plot of selected Sea Island cotton certain rogue plants, all of which possessed the same general morphological characters. It was difficult to account for the appearance of these rogues, since the plot in which they occurred was the outcome of single plant selections made from 1910 onward. The seed from some of the rogues was kept separate and planted in progeny rows. Crosses were made between the rogues and ordinary Sea Island plants to see if any light could be thrown on the inheritance of the rogue characters

GENERAL DESCRIPTION OF THE ROGUES.

The main stem ceases to grow at a very early stage, so that the maximum height is less than 2 feet 6 inches.

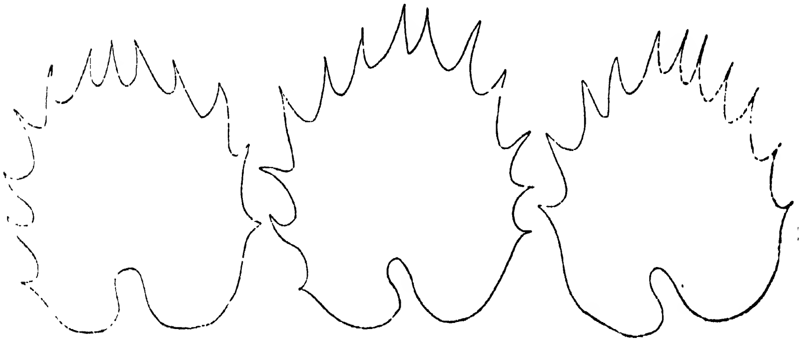
The plants are often without monopodial branches, but one or two of the latter, about equal in size to the main stem, may be present. The production of fruiting branches both from the bud in the leaf-axil and also from the accessory bud, is extremely characteristic. The first flower appears in about eight weeks after the seed is sown, i. e., at the same time as ordinary Sea Island, but a large number of flowers are produced in a short space of time, owing to the substitution in a high degree of sympodia for monopodia. Thus a single plant, sown on December 20, produced its first flower on February 23. In six weeks 115 flowers were counted, which would have given in the neighbourhood of ¾-lb. of seed-cotton if the bolls had reached maturity. The tendency to boll-shedding in the rogues is so pronounced, however, that 95 per cent. of the bolls were shed. In other plants all the bolls dropped.

The leaves are much smaller than those of Sea Island. They possess a peculiar appearance owing to patches of lighter yellowish-green being distributed over the surface. The leaves invariably have torn and ragged edges, and are characteristically crinkled.

BRACT DRAWINGS.

FIG. I.

SEA ISLAND.



ROGUE.

THE F_1. GENERATION.

SHOWING DOMINANCE OF LONG TEETH OVER SHORT

There is a general reduction in the size of all the vegetative parts. The internodes, the teeth of the bracts (Plate 1), the length of the lint, and the flower parts are all shortened. The average seed weight is less than that of ordinary Sea Island.

To sum up.—The crinkled dwarf rogues in Sea Island cotton are characterized by their crinkled, mosaiced leaves with ragged edges, by the extreme development of the sympodial habit, by the reduction in size of practically all parts of the plant, and lastly, by the great tendency of boll-shedding resulting often in sterility.

PURITY OF TYPE.

As already stated, some of the rogues produced no ripe bolls, and it will be seen that it is difficult to obtain self-fertilized seed. A few bolls, however, were obtained from two of the plants, and the seeds when sown threw rogues only, the number of plants being twenty seven in one case and eight in the other.

Progeny rows from other rogues were grown, using seed not self-fertilized. The majority of the plants produced were rogues. One or two Sea Island plants, appeared however, and the presence of these is almost certainly due to cross-fertilization with neighbouring Sea Island plants.

THE F/1 GENERATION OF THE CROSS SEA ISLAND BY ROGUE.

A large number of different crosses were made between rogue and Sea Island. The first hybrid generation was uniform, and indistinguishable in appeearance from Sea Island. It is therefore unnecessary to give details of the various crosses. It appears that the Sea Island characters are completely dominant over those of the rogue.

THE F/2 GENERATION.

In the second generation segregation occurs into Sea Island and rogue. On the first classification the following number. were obtained :—

173 Sea island.
53 Rogue.

Later, however, it was observed that one of the rogues was throwing off some, at least, of the rogue characters, and leaves of the normal colour appeared. The hypothesis which was developed to explain the relationship between rogue and Sea Island was that the rogue may be considered as a retrogressive mutation due to the loss of a single factor. Although the proportion of rogues is rather less than expectation, the number strongly suggests simple Mendelian segregation. The rogue plants, moreover, are very weak in constitution and easily succumb in the seedling stage to the attack of the angular spot disease, or are destroyed by mole crickets This may account for the low number of rogues. The appearance of the abnormal type alluded to above renders further work necessary before the hypothesis can be considered established, and the behaviour of its progeny will be watched closely.

WEST INDIAN COTTON CONFERENCE, 1916.

CONTRIBUTIONS TO THE DISCUSSIONS FROM MANCHESTER.

In continuation of the account of the Proceedings at the Cotton Conference held at St. Kitts last March, and published in the last number of the *West Indian Bulletin* (Vol. XV, No. 4, pp. 235-329), two important letters dated August 12 and 8, respectively, have been received by the Imperial Commissioner of Agriculture from Dr. Lawrence Balls and Mr. John W. McConnel, commenting on the proceedings. The results of Dr. Lawrence Balls's researches on the cotton plant in Egypt, and later on raw cotton at Manchester, were frequently alluded to during the Conference, and his views on the matters discussed, published below, are of much interest and importance. The remarks of Mr. J. W. McConnel, as vice-Chairman of the Fine Spinners' and Doublers' Association Limited, are equally valuable, more particularly from the commercial standpoint. These letters are published in the form in which they were received, as they may be regarded as continuations of the discussions of the Conference.

Dr. Balls writes as follows:—

I have now read your Cotton Conference Report, and have put together some notes on the matter of it, which I hope may be of use to you. It gives me great pleasure to comply with your request in this respect, especially since the Conference in question seems to me to be quite exceptionally useful, not only to the West Indies, but also to workers on cotton elsewhere, and in its scope and treatment is a model which other countries might well copy.

The first thing which occurs to me is, that if I were in the West Indies I should not feel quite happy with the yields obtained. The competition of Egypt is staved off for a few years, but natural causes must ultimately lead Egypt into supplying superfine cotton, . . . excellent 200^s has already been spun from Egyptian-grown staple, . . . with yields of more than 300 lb. of lint per acre. In fact, I see no reason why the yield from such cotton, bred for the purpose, should be any lower than the average Egyptian yields, which, as you know, even now average some 450 lb. per acre, and will ultimately increase to the old level of 550 lb. I am not in a position to compare the cost of production in the two cases, but I have a feeling that the West Indies ought to be able to do better than at present, even allowing for the small size of the Sea Island boll.

The question is, how to improve matters? I take it that the first step is to ascertain in what way the yield is built up under ordinary West Indian conditions, viz. number of flowers formed, number of bolls held un-shed, weight of the boll contents, etc., and to compare these data with one another inside the West Indies and with my published data from Egypt. ('Analyses of Agriculture Yield,' Parts I, II and III, *Phil. Trans. Roy. Soc.* 1915-16.) The data given in the report appear to preclude limitation by manurial supply, just as our old 'unanalysed'

data did in Egypt; yet I found very conspicuous and important manurial effects after I had got behind the predominant water-table effect.

My ideal arrangement of an Experiment Station would make the obtaining of data on such matters a piece of pure routine carried out by unskilled trained labourers (plant observers) and a computing clerk, with a minimum of supervision. The Station would consist of three units under a common scientist-chief, with an agriculturist as assistant and manager. The nucleus would be the laboratory, with not more than 5 acres of land surrounding it, for all kinds of precision field-experiments, permanent plots if desired, and equipment for tackling at least elementary problems in chemistry, bacteriology, microscopy, physics, statistics, and instrument-making. Adjacent to the laboratory, and fed from it, would be the seed-station, of 50 acres or more, with stores and a power-gin, arranged chiefly to allow of meticulous care in handling the seed, and provided with gauze cages. Controlled from the laboratory, but scattered all over the district, would be a number of Observation Stations, where voluntary helpers and trained plant-observers from the laboratory would take record daily on scattered groups of plants, sending their data to the laboratory to be collected and studied, to be summarized and published as crop reports, and to be used in preparing scientific forecasts of a non-subjective nature. You will note that these records would take the place of more extensive meteorological records (*W. I. B.*, XV., p. 263); instead of recording the weather, and—shall I say—guessing its possible effects on the crop, I would prefer to record the crop itself, and deduce the agricultural significance of the weather in that way.

In sketching this ideal Experiment Station and its satellite observation points, I have wandered a little from the yield question, but the connexion is clear, I think. Given statistical data as to how the yield is built up not merely at the laboratory, but all over the district, on good land and bad, it is very easy to see whether and where the gaps in the 'yield-curve' can be patched up.

Such data also enable a very clear distinction to be drawn between the effects of constitution and of environment, i.e., of seed and of cultivation. At present, except in your own remarks, I did not find quite the clarity of distinction in the Report, which I should have liked to have seen.

Again, variety testing is a very simple matter within such an organization. Observation rows of the new variety are intercalated amongst the observed plants at the outlaying stations, with due precautions as to 'scatter', and in this way we can obtain very full and eminently trustworthy data from a dozen different places out of a single kilo of the new seed. That is an economy, as compared with the breeding of many kilos of seed and the sowing of many acres a year or two later.

My remaining remarks will, I hope, be more directly relevant to the Report itself, in dealing with seed-breeding topics.

In the first place I should like to quote two rules, neither of

them my own, which I have come to regard as the Alpha and Omega of conduct in cotton investigations. One is 'Never smooth any Curve.' The other is 'Never mix Seed.' They are very good rules to hold by until the last resort in problem-solving, and they make for scientific precision in economic work. I gather, from Mr. Harland's work in particular, that these rules are already obeyed in the West Indies, but they are worth recalling.

[Mr. Balls then goes on to make a few remarks in regard to the question of 'pure strains', pointing out that his Egyptian pure strains were pure, not merely in lint characters but in every observable character. Reference is made to statements having reference to these strains in the *Egyptian Agricultural Journal* (Vol. V, Pts. 1 and 2.)]. Continuing he says:—

However, in the case of all my pure strains it should be noted that they were bred and studied in the first instance *not* for characters necessarily of economic importance, but in order to study the fluctuation of all kinds of odd features such as the angle which lateral veins make with the mid rib of the leaf, the ratio of the length of the style and the column in the flower, and so on. (*The Cotton Plant in Egypt.*)

Consequently, when certain of them which produced saleable-looking lint were brought into cultivation for trial, they were pure strains as regards commercial characters quite incidentally, being pure strains in respect of every feature which I could see, measure, or estimate—even in respect to the percentage of salt (NaCl) which they would take up from the soil into their cell-sap. (*Cambs. Phil. Soc. Trans.* 1911)

I believe that their success—and later evidence has shown that they were most decidedly successes from the spinner's standpoint at least—was due to this ostensibly absurd refinement. I would not like to assert that there is any characteristic of the plant which might not react by 'autogenous fluctuation' on the properties of the lint. For instance, had I ever found a plant of strain No. 310 which was holding its bolls properly near Cairo, or one of No. 77 which was not red, wizened, and unhappy in the northern Delta, I should have thrown that plant out of sight—keeping its seed for further study, be it said.

In the same connexion I would advise very great care even to abstention, in the use of the word Mutation. A mutation is the easiest thing in the world to assume, and about the hardest to prove. There has been too much loose thinking, prejudged opinion, and misconception in the economic botany of cotton already, when a well-known American made confusion worse confounded by importing 'mutation' as the equivalent of that blessed word Mesopotamia. I had hoped to obtain some positive evidence from the propagation plots of my pure strains in Egypt, undoubtedly the finest material one could have had. In 1913 I kept a very careful look-out, every plant being examined in, e.g., a population of some 20,000 plants of No. 77 strain; in spite of exaggerated care in handling the seed, some twenty rouges were found. These were mutations? Not at all. Fifteen of them were a couple of inches out of alignment with their

neighbours, and were therefore self-sown strays, excepting a couple which had sprouted from old stumps. The remaining five were in their proper places; of them one was an Asia Minor cotton, one seed of which had stuck inconspicuously and tightly in the corner of a canvas sack; three more were traceable to known varieties by natural crossing because a workman was recorded as having damaged the gauze of the cage with his hoe one morning, and there was one plant left on which the verdict was 'not proven.' One plant in twenty thousand. This plant may have been a mutant, and I hope to show that it was, but I am fairly sure that it was not.

Certainly the chance of mutation should be strictly borne in mind, but, I do not think that it need spoil any cotton-breeder's sleep o' nights. There are so many other immediate sources of error. I found mice to be one: they drag seed-cotton from one sack and then from another.

The next matter which occurs to me is the paucity of methods available for studying cotton. I feel myself guilty in that I had not worked more of such methods before I left Egypt, but in extenuation I might plead that I had scarcely reached the lint of all having been busy with the root and stem. Also, I hope to provide some methods in the future. What is needed is a battery of scientific instruments, possibly not quite cheap but absolutely reliable, which will give us the percentage of hairs of every length in a sample, classified in millimetre stages, the breaking strains of the hairs, and possibly some other data. Further, having obtained such data we must know how they bear on the spinning properties of the cotton. Lastly, the methods must not take too long to work; if five to ten samples could be handled in a day. I think they would be useful.

I am sorry to see that the statistical investigation of your West Indian method for determining percentage of weak fibre is not encouraging. I had always thought that there were too many variables involved. I might suggest however, that a great deal of the high P.E. in this method, as well of the lower P.E. in other determinations, is due to our habit of comparing incomparable things, to wit, bolls which ripen at different times. I began during my last year in Egypt a method by which any material destined to be used in stringent comparisons was specially prepared in advance so as to eliminate this error: the plants were picked over clean, then left for not more than a week, and picked again, this latter picking being used for comparisons. It reduces the number of bolls available per plant to a very small number, and increases the 'boll-individuality' error thereby, but it at least insures that all the bolls have undergone similar experiences, even if they have not reacted in the same way to those experiences. You will see from the big diagrams in my 'Raw Cotton' that a week is the longest period possibly allowable.

The papers by Mr. Harland, and by Harland and Amie, pleased me very much. Their critical analysis of the 'ribbon-width' measurement is most valuable, and I am glad that they left the paper as it was written (p. 289). Harland's remarks on Mr. O. F. Cook's discussion of ginning per cent., are quite

justified; there is no necessary connexion between out-turn and seed weight; quite independently both Martin Leake and I have shown, one in genetics and the other in physiology, that the ginning per cent., is determined, constitutionally or environmentally, by the number of hairs which sprout on seed.

Dr. Tempany seems to have overlooked the fact that in 'Raw Cotton' I pointed out the difference between absolute values of measurements of lint length made by my 'halo method' and by pulling, and that I gave two pages of comparative statistics in the appendix. A length-sorter such as I have already mentioned would render both methods obsolete; meanwhile, I am glad that you have found the halo method reliable and speedy.

You rightly pointed out that I practically disregarded the question of the short lint. Not that it is unimportant in Egypt, for Sakel has quite a lot of it. I had to leave it with very scant discussion because there was no method of measuring its amount precisely. Conversely I have not found much mention in the report of the systematic variation, a definite constitutional peculiarity, as one passes round the seed from the butt from the stalk.

This letter has run out to inordinate length, but in conclusion I should like you to permit me to say that I am not quite sure of the meaning of the scheme on page 32) with regard to Repeated Selection. There seems to be a conflict of ideas, possibly of the old and the new.

If the original strain chosen is a genuine pure strain, and has been strictly self-fertilized, selection is useless: to use slang, any old seed will do, plump or wizened, so long as it will germinate, and it can be trusted to carry on the stock unchanged as safely as salt can be trusted to sweeten one's *Chota hazri.* If, on the other hand, the strain is not a pure one, no system of seed-renewal should be risked. Seed-renewal from a central stock is dangerous if that stock is not homogeneous and constant through the years, because it may well happen—indeed, it must happen, that in successive years the renewal supply sent out will not always be the same thing. At the best it will contain varying percentages of the same thing, and natural selection will operate on it with varying effects in consequence.

I am hopeful that the insight which I am acquiring into the uses and vices of the raw material may enable me to be of some direct use to my grower-colleagues of the past and in the future, and I am very glad that the West Indies is in a position to utilize immediately and skilfully any such results.

(Sgd.) W. LAWRENCE BALLS.

The following letter was received from Mr. J. W. McConnel:—

The *West Indian Bulletin* (Vol. XV No. 4) just received, is of very great interest. I had already read the shorter reports of the Cotton Conference in the *Agricultural News*, but this fuller account of the proceedings is much easier to follow, and suggests

many matters in regard to which I think some remarks from this side may be helpful to the fuller understanding of the subject.

There are two things I shall not deal with, viz. the business relations suggested between the Fine Cotton Spinners' and Doublers' Association Limited and the growers, nor the purely scientific question about the respective place of heredity and environment in improving Cotton.

In the first place, I must compliment you all on the excellence of the whole of the papers and discussions at the Conference. The general scheme of the Agenda could hardly have been improved, and what was said was not only useful in itself, but also suggestive for the right consideration of the subject. I only regret that I could not be present myself, but I hope that in any future conference some of us may be able to take part.

In what I have to say I will begin with some remarks on the kinds of cotton that are wanted by spinners. Your own remark on page 275 is perfectly correct. There are in the various islands satisfactory strains of cotton, and the primary aim of your scientific workers ought to be to retain and continue to reproduce these strains It is important to distinguish between two separate kinds of scientific work. There is the search for improvement whether in breed of cotton or in method of cultivation. That is the proper object of experiment work. But there is also the ever continuing necessity for maintaining a pure fount or origin for seed of the type or types which are for the time being adopted for use in general cultivation. This is strictly the work of the Seed Farm. It may be convenient to have Experiment Station and Seed Farm together under the same chief, but the two have different objects. We must have a starting point for experiment work, and the cotton that is now grown in the West Indies is satisfactory except for its waste and its 'nep'. It will at any rate do to go on with. The thing that is absolutely necessary as the foundation of all improvement is to be able to purify, if necessary, the strains you have now, and to maintain them uncontaminated and unaltered. In this connexion I may say that almost the only thing said that I entirely disagree with is on page 273, where Mr. W. Nowell quoted the experience of Barbados as showing that seed from mixed types would give satisfactory lint. I do not think the best cotton growers in Barbados would accept this description of their ideals, and so far as it is the practice in Barbados, it may explain the great falling off there has been for many years in its production of cotton. Certainly everything seems to show that uniformity is the most important characteristic in cotton, and that uniformity is impossible except from pure strains.*

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* 'Lint satisfactory to the Spinner' was the phrase used; his satisfaction being gauged by the price he was willing to pay, which, until very recently at any rate, equalled that paid where much more careful methods were applied in obtaining the seed actually used for the crop. W.N.

How many types or strains are wanted by spinners? This is an impossible question to answer at present because we cannot define what is meant by a type. There is a very wide range of counts spun from West Indian Cotton. I suppose you all understand that by 'counts' is meant the number of hanks of 840 yards each that weigh 1 ℔. The ordinary range of counts spun in Great Britain is from, say, 40s to 200s. For this American Egyptian and Sea Island Cottons are used. But the range for which West Indian Cotton is used starts at, say, 120s and reaches up to 350s, 400s or even finer. Thus it is obvious that there must be room for a good many degrees of what we call 'Fineness' in the cotton itself. The speakers at the Conference seem to imply that there are only two types, viz. the ordinary and the superfine St. Vincent. In practice, from the spinner's point of view, there must be many more classes than this; though how far these different classes are the result of different parentage, and how far they come from different soils, and how far the cotton of the same parentage grown on the same soil varies from one season to another, it is beyond me to say.

The practical thing to be done is to go on for the present as we are doing; you on your part to purify your strains, and to make certain of keeping them pure; we, on the other hand, to elaborate our testing arrangements; and both to work for the common end of knowing exactly what is wanted and being able to grow it.

Improvement will come with time. But it is important to remember in what improvement really consists. References are made to cottons which realized higher prices than usual. (See p. 271 for St. Vincent, p. 272 for St. Kitts, and on page 267 Montserrat trying to find a higher priced cotton.) These may or may not be real improvements. The first consideration to my mind for the grower is the average value per acre: 300 ℔. at 14*d.* is better than 120 ℔. at 20*d.* This consideration is important also in the interest of the spinners. And again you must remember one small but very important point, viz., that some special lot of cotton might command a high price because of its extra length and fineness, and yet if it were grown on a larger area the extra quantity might be in excess of the demand for yarns so fine, and then the market price would fall. Two buyers to one seller make a high price, two sellers to one buyer make it low. In regard to an article of such exceptional character as the finest types of West Indian cotton, proper regulation of the quantity required at any time can only be obtained by systematic consultation between spinners and growers, and we must make it our business to find some plan by which this can be done on terms which are fair to both.

What then is meant by improvement? Well first, there is the removal, partially or entirely, of known defects, both those due to seed and those due to circumstances. The great merit of West Indian cotton has always been its strength, that is not only is the yarn made from it strong, but the fibres when handled do not readily tear. And yet the great defect of West Indian cotton has always been that more than any other fine

cotton in general use, it makes 'neps'. You and Dr. Tempany have told me in the past that these 'neps' are largely derived from the hairs grown near the raphe of the seed. Whatever the cause is, here is a definite thing for Experiment Workers to cure.

Then as time goes on they will gradually find—partly by improved cultivation, partly by more complete avoidance of pests, and partly perhaps by better strains of cotton—how to increase the production per acre without decreasing the spinning quality of the type.

Whether the spinning quality of any type can be also improved with time is a more complex question. because it depends not only on whether the grower can do it without a disproportionate decrease in quantity, but also because it depends on whether the spinner wants an improvement. The spinner's ideal would be that perfect cotton should be grown of varying degrees of what we call Fineness so that all counts of yarns from the coarsest to the finest would be equally good. And he would, in an ideal world, expect the quantities of each class to be proportionate to the quantity of yarn required of each. And again the price, ideally, should run in regular sequence comparable to the increasing 'Fineness' of the cotton. The Ideal can never be reached, but human effort should always be directed towards its attainment: and the hope of the future in regard to this particular little part of the cotton trade is that the growers of West Indian cotton should work in close co-operation with the few spinners who can use it. And in this way, as time goes on, the spinners will be able to explain to the Experiment workers what degree of greater 'Fineness' will be advisable. Or it may be the other way; it may sometimes be possible to point out that a cotton of less 'Fineness' can be used on a considerabe scale if it can be produced more prolifically and consequently at a lower price.

And this brings me to the question of practical mill tests. And in regard to these I should like to say that at any rate for the present I do not contemplate that mill tests will take the place of judgment by touch in buying and selling. This question is asked on page 292. One reason for this is that brokers and merchants know nothing about mill tests. For the present the real value of mill tests is that they enable us to tell Experiment Workers something of a definite character instead of giving a mere opinion, and what the mill test says to-day will in a year or two be the opinion of those who judge by touch.

You may take it for granted that the Fine Spinners' Association will co-operate to the utmost of its power in this matter of mill tests. But there are one or two qualifications to be named. First the time and attention required for a test, and the interruption of the ordinary mill routine are much greater in a Sea Island Mill than in others. Therefore we do not want to have an unnecessary number of samples. Secondly, I think we may fairly ask for very full information to be given us as to what is aimed at in any particular sample. In reading the *Bulletin*, I have marked many places where I should like to have had samples for trial. St. Kitts No. 342 S

on page 264, Montserrat cotton pp. 267, 268, St. Vincent pp 270, 271 and others. But it is very likely that I have actually had these samples to test without knowing what they were Apart from the fact that we take a natural interest in the matter, I am sure our judgment will be much more useful if we are given full information. A cotton may be very useful in a lower range of counts, even if not 'Fine enough for a higher And certainly all the assistance Dr. Lawrence Balls will be able to give in this matter will be much greater if full information is given.

There is a definite resolution on page 293 asking the Fine Spinners' Association to furnish detailed information of the behaviour in the mills of particular marks of cotton. This it is hardly possible to do in connexion with the ordinary working up of the cotton, for it is very seldom that one particular lot is used entirely by itself. But I think we could add to our special tests of experimental samples a limited number of samples of actual commercial crops. And indeed to do something of this kind might make our reports on experimental samples more intelligible and useful. Suppose for instance, Montserrat has a particular variety in the experiment station which is hoped to be an improvement on one side of the island, it would make our report much more definite if we had at the same time a sample of what was locally considered to be one of the best crops of the existing type of cotton.

(Sgd.) JOHN W. McCONNEL,
Vice-Chairman,

Fine Cotton Spinners' &
Doublers' Association Limited.

(Pages 1—93, issued October 31, 1916.)

NOTE ON THE RECOVERY OF SUGAR AT GUNTHORPES FACTORY, ANTIGUA, 1905-16.

BY SIR FRANCIS WATTS, K.C.M.G., D.Sc., F.I.C., F.C.S.,

Imperial Commissioner of Agriculture for the West Indies.

The completion of the manufacture of the sugar crops of twelve seasons by Gunthorpes Factory, Antigua, provides an interesting collection of data from which may be gathered the average composition of the canes dealt with in each season, and the efficiency of the factory in handling them. These data are of the greater interest, seeing that they have reference to a factory in successive stages of development, and so afford valuable information as to the efficiency of different forms of equipment, and of the value of the additions and improvements that have been made.*

The average composition of the canes supplied to the factory in each year from 1905 to 1916 is stated in the annexed table, regard being had to the content of sucrose and fibre.

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* A review by the same author, of ten years' work of the Gunthorpes Factory (1905-15) appeared in the present Journal, Vol. XV, No. 2. An account of the origin and early stages of the factory's progress was given in Vol. VI, p. 60, and this was supplemented by some account of the first three years' working, by a further article in Vol. IX, p. 79.

COMPOSITION PER 100 PARTS CANE.

Year.	Fibre.	Sucrose.
1905	15·1	15·3
1906	15·2	14·1
1907	15·1	14·4
1908	15·2	14·3
1909	15·6	14 2
1910	15·9	14·7
1911	15 8	14·1
1912	17·5	14·2
1913	17·7	12 9
1914	16·6	13·5
1915	16·9	12·0
1916	16·2	12·5

The estimation of the fibre content of the canes supplied to a factory presents peculiar difficulties; it is impossible to obtain samples that will correctly represent the whole; consequently it is felt that information based on the analysis of samples, however carefully obtained, is of little value. At Gunthorpes the amount of water used for maceration is not directly measured, consequently the formula, Megass = Weight of Cane + Weight of Water - Weight of Juice, cannot be used. After considerable discussion with the chemist of the factory, it has been decided to use the following formula:—

$$\text{Fibre in Cane} = \frac{100 - \text{Crushing} \times 100}{128 + \text{juice per 100 fibre in megass.}}$$

This formula appears to be the best that can be found to meet the conditions; it is readily applied, it deals with the whole of the material going through the mills, and is believed to give concordant and useful results. It appears to give more reliable information than can be obtained by the analyses of samples of canes. It has, however, the defect of being affected by any loss in weight by drying that the canes may experience between the time that they are weighed and the time that they are crushed, in consequence of which the fibre may be slightly over-estimated. This aspect of the case is being investigated.

Inspection of the table shows that the amount of fibre in the canes dealt with has been unusually large; it has shown

a tendency to increase in later years: at first it was thought that the increase in the amount of fibre was largely due to dry seasons, but this explanation does not appear to hold good, seeing that very high fibre contents are met with in 1915 and 1916, years in which there was a good rainfall.

When one turns to the figures relating to the sucrose content, another feature appears which calls for comment and investigation; it is seen that the sucrose content of the cane has steadily fallen off: in 1905 it was 15·3 per cent., and in the period from 1905 to 1912 it ranged from 14·1 to 14·7 per cent., while from 1913 onwards it has only once (1914) risen beyond 13 per cent.

At present no adequate explanation of this variation is forthcoming; the matter is one which requires careful investigation. That it deserves consideration will be recognized when it is stated that a difference of one per cent. in sucrose content, such as between 13·5 and 14·5, would mean an increase in output of little short of 1,000 tons of sugar from a factory making about 14,000 tons of sugar, a point not far beyond the capacity of the factory in question. Roughly it may be said that such an increase in sucrose content would mean a possibility of increased gain of about £1 per ton of sugar produced by the factory, taking the value of sugar at about £14 per ton, or a gain of £1,000 on each 1,000 tons of factory output.

It was thought that possibly the falling off might be accounted for by the undue prolongation of the grinding season, but an examination of the records, while showing that this has some influence, leads to the conclusion that the circumstances are not thus fully accounted for, and that there is a falling off of the sucrose content of the canes even in the better part of the seasons. It is possible that in dry seasons the sucrose content of the cane is increased even more than the fibre content, and that in seasons and places of heavy rainfall the canes contain smaller amounts of sucrose; but even here we are faced with the fact that the years 1909, 1911, 1912 and 1913 were years of trying drought but of relatively low sucrose in the canes.

It is hoped that these questions will be investigated and that it may be possible at a later date to throw further light upon them.

The following table showing how the sucrose in the cane has been distributed in the process of milling and manufacture has been compiled from the records of the factory :—

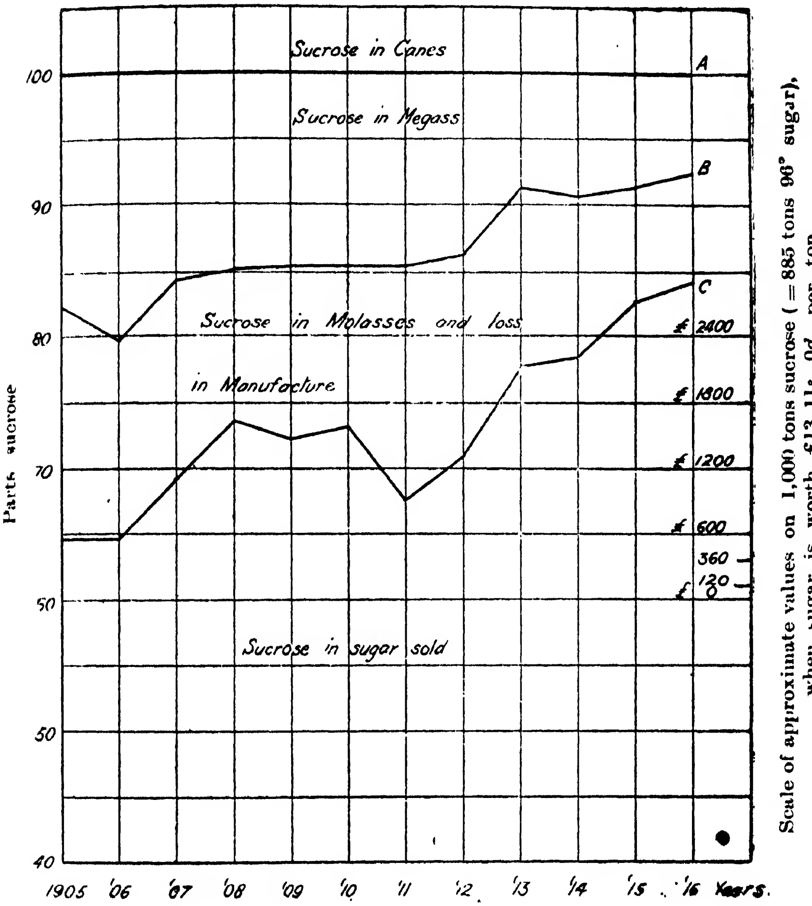
DISTRIBUTION IN MILLING AND MANUFACTURE OF SUCROSE IN CANE PER 100 SUCROSE IN CANE.

Year.	Sucrose in megass.	Sucrose in juice. (Indicated sucrose.)	Sucrose in molasses and lost in manufacture.	Sucrose in sugar sold.	Commercial sugar sold per 100 sucrose in cane.	
1905	17·9	82·1	17·4	61·7	67·4	6 roller mill
1906	20·4	79·6	15·0	64·6	67·5	
1907	15·6	84·4	15·0	69·4	72·2	8-roller mill
1908	15·0	85·0	11·3	73·7	76·7	
1909	14·6	85·1	12·9	72·5	75·4	
1910	14·7	85·3	12·1	73·2	76·1	
1911	14·6	85·1	17·8	67·6	70·5	14-roller mill
1912	13·8	86·2	15·2	71·0	73·9	
1913	8·9	91·1	13·5	77·6	80.9	
1914	9·4	90·6	12·3	78·3	81·7	
1915	8·7	91·3	8·7	82·6	85·8	
1916	7·8	92·2	7·7	84·5	88·0	

The information is also given in graphic form in the annexed diagram, from which the significance of the facts can be more readily appreciated.

GUNTHORPES FACTORY, ANTIGUA.*

Distribution in milling and manufacture of sucrose in canes.



Years.

The line A in the diagram indicates the total sucrose in the canes of each year: the curve B indicates by its distance from A the amount of sucrose left in the megass. The curve B measuring from the bottom of the diagram, shows the proportion of sucrose extracted in the juice – the 'indicated sucrose' of sugar chemists. The curve C gives the proportion of sucrose recovered and sold as sugar, while the space between the curves B and C indicates the proportion of sucrose in the molasses and lost in manufacture.

Consideration may first be given to the work of the mills. In the first two years it is seen that 18 to 20 per cent. of the sucrose in the cane was lost in the megass, while in the last four years this loss is reduced to less than half.

* In the reproduction of the diagram the space from 40 down to 0 has been omitted. In judging by the eye, it must be borne in mind that the real base of the diagram is 40 divisions below the base as at present drawn.

It is to be observed that the work of the first two years was done by means of a 6-roller mill; in the third year a Krajewski cane crusher was added, making the mill an 8-roller one. This condition continued until 1911 when six more rollers were added, converting the mill into a 14-roller train.

The work of the 8 roller train resulted in megass carrying away a little under 14 per cent. of the sucrose in the cane, the work being very uniform.

The operation of the 14-roller mill in 1911 appears to have effected no improvement over the work of the 8-roller mill, but the factory records show that this year was a trying one on account of drought, and that little water was available for purposes of maceration: during this season the work of the factory was carried on with much difficulty. In the succeeding year the mill work improved slightly but was still unsatisfactory. This also was a year of drought, though more water was available for maceration than was possible in the previous year.

In 1913 the mills were efficiently worked notwithstanding the fact that the season was also one of serious drought: the sucrose lost in the megass was now brought down to less than 9 per cent. of that in the cane. In the following year it was 9·4 per cent, and was 8·7 and 7·3, respectively, in the last two years of the factory's working.

These last four years reveal creditable work when it is remembered that the canes dealt with contain some 16 to 17 per cent. of fibre.

The diagram shows at a glance the limited scope that exists for further improvement in milling, not that it is held that further improvement is not to be attempted, but it shows that further gains can only be relatively small; they are likely to be somewhat costly and troublesome, and it is evident that if they are to be attempted, it must be as the outcome of careful calculation and planning. Haphazard or rule-of-thumb work is likely to be far from profitable in this field.

The diagram may be used for purposes of ready approximate calculation of the monetary values of the quantities dealt with. A scale is drawn on the right-hand margin for this purpose: it has reference to a hypothetical factory receiving 1,000 tons of sucrose in its canes, and turning out about 885 tons of commercial sugar from them. On this basis, when sugar is selling at £13 11s. 0*d.* per ton, 10 per cent. of the factory output, i.e, 10 per cent. on the diagram, is worth £1,200, or 1 per cent. is worth £120. These and other values can be readily measured off on the diagram by means of dividers.

In the case of a factory receiving 10,000 tons of sucrose and turning out about 8,850 tons of sugar, the values for division would be tenfold those stated above.

Regarded in this way, we see that the difference between the 8 roller and the 14-roller mills may be taken at rather over 5 per cent., so that in a small 885-ton factory, the gain from the 14 roller mill would be some £600, or in an 8,850-ton factory, a gain of £6,000. At Gunthorpes with an output of 12,000 tons,

the gain would be about £3,100, with sugar selling at £13 11s. 0d. per ton. The value of good milling is thus abundantly clear.

It may be noted that the value of the sugar lost in the megass even from the 14-roller mill is approximately £1,000 for the 885-ton factory, or £10,000 for an 8,850-ton factory. This seems to indicate that the economical limit of crushing may perhaps not yet have been reached.

These figures and the general aspect of the diagram plainly show the overwhelming importance of good milling.

Much interest attaches to the curves B and C, the space between which measures the efficiency of the factory work subsequent to the mills.

In the first three years of the factory's existence about 15 per cent. of the sucrose in the cane remained unrecovered in the molasses or was lost in manufacture. In the fourth, fifth and sixth years this was somewhat reduced, and was in the neighbourhood of 12 or 13 per cent. In 1911, however, there was a marked falling off in the recovery, the unrecovered sucrose amounting to 17·8 per cent. of the sucrose in the cane. In the next year (1912), the loss was reduced to 15·2 per cent., and in the following year (1913). to a little over 13·5 per cent.

In the last three years the unrecovered sugar has been progressively diminished, the figures being as follows: 1914, 12·3 per cent.; 1915, 8·7 per cent.; and 1916, 7·7 per cent.

It is instructive to consider the monetary values represented by these figures. Taking the recoveries of the early period 1908, 1909 and 1910, when the unrecovered sucrose was about 12 per cent., and comparing them with the two last years when, on the average, only some 8·2 remained unrecovered, we have a gain in recovery of 3·8 per cent. On the basis of the monetary scale above referred to, this represents a gain of £450 in a factory producing 885 tons of sugar, or £1,500 in an 8,850-ton factory. At Gunthorpes, making 12,000 tons, the monetary gain is equivalent to £6,100.

During the years of poor recovery the canes were of inferior quality and the juice was, in consequence, difficult to work. In recent years the equipment of the factory has been improved, both as regards appliances and technical skill, with results that are satisfactory.

It is important to note that whereas in the early history of the factory some 65 per cent. only of the sucrose in the canes found its way to market as commercial sugar, in the last year the figure reached 81·5 per cent.—an increase of 19·5 per cent. Had Gunthorpes factory remained in the condition in which it was first erected, there would have been lost last year sugar to the value of £30,370 on a crop of 12,000 tons, at £13 11s. 0d. per ton. This does not imply that by the recovery of the additional amount of sugar the whole £30,370 was gain to the factory; only part of this is profit, for there is expense entailed in extra machinery and extra cost in working to ensure the higher recovery; but even allowing for this, there remains a substantial margin of profit.

Consideration of facts and figures such as these enables one to form a clear idea of the possibilities and requirements of the sugar industry as regards the manufacturing side. It is obvious that with the aid of high scientific and technical skill, it is possible to recover a very large proportion of the sugar in the cane that was formerly lost, and that some further improvements are conceivably possible, though this will only be at the expense of knowledge and skill.

It is also obvious that ill-equipped factories may fall very short in their recovery of sugar, so that, should a time of low prices and keen competition again arrive, as is almost certain to be the case, such ill-equipped factories may find their businesses unprofitable.

. Such considerations enforce the arguments for the provision of a supply of highly trained skilful chemists and sugar technologists, and they point to the fact that while every effort may legitimately be made to protect the sugar industry from unfair competition such as it has for years experienced, it will be unwise not to use every effort to ensure as perfect working of the factories as knowledge permits, for it is clear that large gains lie in that direction.

The aspects of the modern sugar factory thus set out lead to a consideration of the manner in which the return of sugar has been estimated by West Indian Sugar Growers within recent memory, and the changes that have taken place therein.

Not very long ago it was the custom to report the output of sugar in terms of the number of hogsheads made on each estate, and then in terms of hogsheads per acre. The hogshead being a somewhat vague quantity, the statements were subsequently made in terms of tons. In this way the operations of the field and factory were not separated; there was thus little opportunity of judging as to the relative efficiency of field and factory.

With the advent of central sugar factories it became necessary to weigh the canes, whereupon a separation of the returns of field and factory became possible, and planters are able to report the tons of canes reaped per acre—a practice which is calculated to reflect favourably on their work.

At the same time the factories put forward statements as to the number of tons taken to make a ton of sugar. It will readily be seen, however, that this cannot be the final stage, but that in the near future it will be necessary to state the percentage of sugar recovered from the sugar existing in the canes, and to show how this has been extracted by the mills and recovered in the factory. The mere statement of tons of cane per ton of sugar may be quite misleading as to the efficiency of the factory, for a relatively inefficient factory, working with rich canes, may take less tons of canes per ton of sugar than a very efficient one working with poor canes. The following hypothetical cases which are well within the limits of possible happenings may be instructive.

We may compare two factories. We may imagine the first one as dealing with canes containing 14·7 per cent. of sucrose and recovering 77 per cent. of this sucrose in the sugar marketed.

This result might be obtained by a recovery in the juice of 86 per cent. of the sucrose of the cane, which would be good work for an 8-roller mill, followed by a recovery of 89·54 on the indicated sucrose. The final result would be that this factory would recover 11·32 per cent. of the weight of cane as sucrose, or 11·79 per cent. as 96° sugar. This is equivalent to making 1 ton of 96° sugar from 8·48 tons of canes.

The other factory might deal with canes containing 13·0 per cent. of sucrose and recover 83 per cent. of this in the sugar sold. This work might be attained by a recovery by the mill of 92 per cent. of the sucrose in the cane, and the recovery of 90·2 per cent. of this in manufacture. This would result in the recovery of 10·79 per cent. of sucrose per 100 of cane, or 11·24 per cent. of 96° sugar, so that 1 ton of 96° sugar would be made from 8·9 tons of cane.

It might appear, if regard is had only to the quantity of cane taken to make a ton of sugar, that the factory last referred to is doing the poorer work, seeing that it takes 0·42 ton of cane over what the first factory takes to make a ton of sugar.

When, however, the relative quantities of sucrose in the canes dealt with are taken into account, it is seen that the recovery on this second factory is better than that of the first by 7·9 per cent. That is to say, if the first factory turned out 1,000 tons of sugar, the second factory from the same canes would make 1,079 tons of sugar: if sugar is worth £14 a ton, the gain due to the better working of the second factory would be £1,106, or the first factory may be regarded as losing that amount, which is over 22s. per ton of sugar; though it must not be forgotten that the first factory may do its work more cheaply, so that the loss may be somewhat less than stated.

The point to note is, that should there be keen competition in sugar production, and low prices, the second factory might make a profit at a point where the first might make a loss.

THE IDENTITY OF FIBRE-AGAVES.[1]

BY PROF. LYSTER H. DEWEY.

WITH A KEY TO SISALANAE IN THE WEST INDIES.

(BY WILLIAM TRELEASE.)

The literature of Agaves contains many incorrect statements regarding the identity of species. Many botanists who have written about Agaves, have studied only dry herbarium, specimens, or dwarf and imperfect plants cultivated in a green-house (under glass). This has resulted in much confusion. If it were merely a question of difference of opinion as to the correct name, it would be of no importance except to botanists. But it is of much greater importance to the planter. The different species of Agaves are adapted to different conditions of soil and climate, and they are also different in size, quality of fibre, length of life, and in other important economic characters. It is therefore well that the identity of the plants be known.

The following species are the principal ones producing commercial fibres, together with synonyms and references to other names which are confused with fibre-producing plants :—

1 *AGAVE FOURCROYDES*, Lemaire.

Henequen (Spanish name).
Sacci (Maya Indian name).
Weisse Sisal (German).

Synonyms : *Agave rigida elongata.*
Agave elongata.
Agave ixtle.
Agave rigidia longifolia.

Native in Yucatan, Mexico; cultivated in Yucatan, Campeche, Chiapur, Tamaulipas and Sinaloa, Mexico; also in Cuba, and recently introduced into German East Africa.

It is the only species cultivated in Yucatan for the production of fibre for export. In Yucatan, Cuba and elsewhere in Spanish America the name 'henequen' (pronounced hen-ē-ken) is used to designate the plant and also the fibre. In the markets of America and Europe the fibre is usually called 'Sisal' or 'Yucatan Sisal'. It constitutes more than 90 per cent. of the sisal fibre of commerce.

DESCRIPTION.

PLANT. Propagated from suckers, bulbils or seed. Suckers

1. Reproduced by permission of Professor Lyster H. Dewey, from Verslag van het Veselcongres gehouden te Soerabaia van 3 tot 8 Juli, 1911.

are used in practice. Life ten to twenty-five years, develop as trunk 0·5 m. high and 25 to 35 c.m. thick.

LEAVES. Always glaucous (gray-blue), straight and rigid, 1 to 2 m. long, 10 to 15 c m. wide at middle. 6 to 8 c.m. wide, and 5 to 7 c.m. thick (vertically) at the narrow part near the base. Vertical thickness almost equal to horizontal width at base.

MARGINAL SPINES always present, 3 to 4 mm. long, curved with points *downward.* Terminal spine about 30 mm. long.

FLOWER STALK 4 to 8 mm. high, with rather stout horizontal branches, bearing at the slightly upcurved ends, dense clusters of flowers about 6 cm. long, followed by *seed pods* or bulbils.

CONDITIONS OF GROWTH. Henequen will grow well only in a warm dry climate and in a loose well-drained limestone soil. Under good conditions leaves produce 4 to 5 per cent. clean dry fibre.

2. *AGAVE SISALANA*, Perrine.

Sisal, Originally Spanish port of shipment.
Yaxci, Maya Indian name.
Grun Sisal, German.
Henequen, verde Spanish.

Synonyms : *Agave rigida sisalana.*

Native in Central America, Campeche, and probably Yucatan. Cultivated on a small scale by natives for fibre for domestic use in Central America and southern Mexico, but in Yucatan now for fibre for export.

Introduced and naturalized in Florida, but not cultivated there.

Cultivated commercially in the Bahamas, Turks and Caicos Islands, Hawaii. Java, German East Africa, Bengal, and Indo-China. More widely distributed than any other fibre-producing Agave. The name 'Sisal' is better than 'Sisal hemp' to designate this plant.

DESCRIPTION.

PLANT. Propagated by suckers or bulbils. Suckers are preferred, but bulbils are more easily transported.

Life five to ten years ; rarely develops a well-defined trunk

LEAVES. Dark green or slightly glaucous, straight but less rigid than *A. fourcroydes*, 1 to 1·75 m. long, 8 to 14 c.m. wide at middle, 6 to 8 c.m. wide and 2 to 4 c.m. thick (vertically) at the narrow part near the base, vertical thickness at this point always much less than width.

MARGINAL SPINES. Usually none ; sometimes small, curved marginal spines pointing downward. Terminal spine slender, 25 to 28 mm. long.

FLOWER STALK. 4 to 8 m. high with slender branches projecting upward, more than in *A. fourcroydes*; flowers about 6 c.m. long followed by bulbils, *never by seed pods*, so far as reported.

CONDITIONS OF GROWTH. Sisal grows best in a well-drained limestone soil, and in a dry climate, but it will endure a wider range of conditions than henequen.

Under good conditions leaves produce about 3½ per cent. clean dry fibre, whiter and stronger than henequen.

3. *AGAVE CANTALA*, Roxburgh.

Nanas Sabrang (Java).
Manila Maguey (Philippines).

Synonyms: *Agave cantula.*

(*u* a typographical error, which has been copied by many authors. It was spelled *Cantala* in the original description by Roxburgh.)

Agave vivipara.
Agave rigida elongata } in Java.
Agave elongata }

Introduced into Philippines, India, and probably Netherlands East Indies in early Spanish times. Not known in native wild condition in America.

Cultivated in Java, Philippines, and to limited extent in British India.

DESCRIPTION.

PLANT. Propagated from suckers or bulbils. Seed pods not reported. Does not develop a well-defined trunk. Life five to ten years.

LEAVES. Glaucous, usually straight and ascending, but less rigid than in *A. fourcroydes* and sometimes slightly curved; 1·5 to 2 m. long, 8 to 14 c.m. wide at middle, 6 to 8 c.m. wide and 3 to 5 c.m. thick at the thick narrow part near the base.

MARGINAL SPINES. 3 to 4 mm. long, hooked or curved, pointing *upwards*. Terminal spine 1 to 2 c.m. long.

FLOWER STALKS. 4 to 7 m. high, slender, flowers about 7 c.m. long, followed by bulbils. Seed pods not reported.

CONDITIONS OF GROWTH. Manila Maguey grows well in loam soil and even in sandy soil, and endures moisture better than either sisal or henequen.

Finer fibre and more flexible than henequen.

4. *AGAVE FUNKIANA.*

Jaumave lechuguilla.
Jaumave ixtle fiber.
Tampico fiber.

Synonyms: *Agave heteracantha.*
Agave Kerchoevii.

Native in Jaumave valley in the State of Tamaulipas, Mexico. Not cultivated, and very rarely introduced outside of its limited native locality.

DESCRIPTION.

PLANT. With no trunk, length of life not known.

LEAVES. Straight, rigid, green, with often yellow stripe, 1 to 2 c.m. long, wide from base to point on face of leaf, 0·5 to 1 m. long, 4 to 6 c.m. wide, not narrowed at base. Continuous, hard border of leaf bearing spines hooked downward.

FLOWER STALK. 2 to 4 m. high, with slender spike of flowers followed by seed pods, no bulbils.

5. *AGAVE LECHEGUILLA*, Torrey.

Lechuguilla.
Tula ixtle, Fiber.
Tampico fiber.

Note.—The specific name is spelled with *e* as in original description, but the common name used in Mexico is spelled with *u* and pronounced lĕch-ū-gé-yah).

Native on high tablelands of Mexico from State of San Luis Potosi, northward to Texas. Not cultivated. Occasionally introduced into botanical gardens.

DESCRIPTION.

PLANT. Without trunk, length of life not known.

LEAVES. Rigid, nearly always curved to one-side, dark green, often with light strip on face. Strong marginal spines on continuous horny border of leaf hooked downward.

FLOWER STALK. 2 to 3 m. high with slender spike of flowers followed by seed pods.

Fibre called 'tula ixtle' or 'istle' or 'Tampico', is cleaned by hand from central buds or cagallos.

6. *AGAVE ZAPUPE*, Trelease.

Zapupe azul.
Zapupe de Estopier.

Probably native in Eastern Mexico. Cultivated most extensively in valley of Tuxpam River, in the State of Vera Cruz, Mexico, Rarely introduced elsewhere.

DESCRIPTION.

PLANT. Propagated by suckers or by bulbils. Very similar in general appearance to *Agave cantala*, length of life five to eight years.

LEAVES. Glaucous (gray-blue), rigid, 1·25 to 1·5 m. long 7 to 11 c.m. wide; marginal spines red, 2 to 3 mm. long, curved, pointing downwards. Terminal spine about 3 cm. long.

FLOWER STALK. 3 to 6 m. high with rather short branches bearing clusters of flowers usually followed by bulbils.

Cultivated mostly in loam soil of good fertility. Fibre finer and softer than that of Yucatan henequen.

7. *AGAVE LESPINASSEI*, Trelease.

Zapupe de Tepetzintla.
Vincent Zapupe.

Native in Eastern Mexico, cultivated in the region of Tampico. Rarely introduced elsewhere. It does not produce the fibre called 'Tampico'.

DESCRIPTION.

PLANT. Propagated by suckers and bulbils. Similar in general appearance to *Agave sisalana*, but leaves generally shorter. Life six to ten years.

LEAVES. Green, rigid, 1·25 to 1·5 m. long, 8 to 12 c.m. wide, marginal spines, red, 2 to 3 mm. long, curved, pointing downwards. Terminal spine nearly 4 cm. long. Flower stalk similar to that of *A. Zapupe.*

Cultivated mostly in sandy soil near the coast, but it might give better fibre in drier soil or soil with more lime. Fibre finer and more flexible than henequen.

8. *AGAVE DEWEYANA*, Trelease.

Zapupe verde.
Tamaulipas henequen.
Huasteca henequen.

Native in Northern Vera Cruz. Cultivated mostly in region of Ciudad Victoria, Tamaulipas. Rarely introduced elsewhere.

DESCRIPTION.

PLANT. Propagated by bulbils or suckers. Similar to Sisal in general appearance, but with narrower leaves. Life six to ten years.

LEAVES. Dark green, thin and outward, curving somewhat, 1·5 to 2 m. long, 6 to 10 c m. wide. marginal spines red, curved, with points downward. Terminal spine 3 to 4 cm. long, usually slender.

FLOWER STALK. Similar to preceding. Flowers followed by bulbils. Fibre similar to that of *A. Zapupe*, finer and softer than Sisal from *A. fourcroydes*.

9. *AGAVE TEQUILANA*, Weber.

Tequila Maguey.

Cultivated in south-western part of Jalisco, Mexico, near Guadalajara, primarily for 'Tequila wine' distilled from the bases of the plants.

LEAVES. Sometimes used for fibre production.

PLANT. In general appearance very similar to *A. Zapupe.*

10. *AGAVE* sp.

Sinaloa Maguey.
Mescal Maguey.

Cultivated in State of Sinaloa, Western Mexico, primarily for mezcal liquor distilled from bases of plants.

LEAVES. Used for production of fibre called Mescal fibre or Mezcal fibre. Rarely introduced in gardens.

PLANT. Similar in appearance to *A. cantula.*

11. *AGAVE STRIATA*, Zuccar.

Espadin.
Cuapilla.

Native in high mountain valleys, Central Mexico. Not cultivated. Narrow triangular leaves about 10 mm. wide and 40 to 50 cm. long, striate, with no spines. Produces fibre of low grade.

12. *AGAVE FALCATA.*

Cuapilla.

Native in high mountain valleys of Central Mexico. Not cultivated. Similar in appearance to preceding (*A. striata*) except that leaves are slightly wider and curved sidewise. Produces a low grade fibre of little importance. The following species often mentioned among fibre producing agaves are of no real value for fibre production.

13. *AGAVE AMERICANA*, L.

A large-leaved Agave widely distributed in cultivation as an ornamental plant, naturalized in Southern Europe and India, not known in wild state. Fibre of little value, too poor to be worth cleaning.

14. *AGAVE ATROVIRENS.*

Pulque Maguey.

Cultivated as are other large-leaved Agaves, commonly called Magueys in Central Mexico, for production of 'pulque', a popular drink made of the fermented juice.

15. *AGAVE DECIPIENS*, Baker.

False Sisal.

A small plant native on the Florida Keys. It is said to have been substituted for Sisal, but it may be easily distinguished by its short (0·5 m.) leaves curved backward, and of an apple-green colour similar to bitter aloes.

16. *AGAVE IXTLI*, Karwinski.

Native in sandy land on northern coast of Yucatan. Similar in general appearance to a dwarf henequen (*A. fourcroydes*). It does not produce any of the ixtle fibre of commerce, and does not grow within 400 miles of where ixtle fibre is produced.

KEY TO SISALANAE IN THE WEST INDIES.[2]

Medium-sized or large suckering subacaulescent or caulescent plants with rather numerous firm and rigid, straight, narrow gray or somewhat glaucous dull smooth leaves with openly grooved not decurrent spine and rather small subdistant prickles (rarely all but lacking); ample oblong panicles; medium-sized or large greenish fetid not congested flowers with maroon-dotted filaments and style, abundant inflorescence bulbils; and, when produced, moderately large capsules and large seeds.

Continental plants introduced into a few islands. Spine tortuous, flat-topped; prickles very slender from deltoid bases. *A. angustifolia.*

Spine slightly arcuate, grooved toward the base; prickles (if present), gradually tapered.

Caulescent, gray-leaved, armed. *A. fourcroydes.*

Acaulescent, greener, at most with reduced prickles. *A. sisalana.*

Agave fourcroydes (Lemaire).

Caulescent, the trunk at length 2 m. high, suckering. Leaves dull gray-green, linear lanceolate, openly concave, 8-10 by 150-250 cm.; spine blackish brown, or gray in age, sometimes pitted and glossy, stoutly conical, slightly recurved, round-grooved below the middle, 4-6 by 20-30 mm., not decurrent; prickles blackish, usually 10-20 mm. apart, 1-4 mm. long, straight or gently curved, especially upward, narrowly triangular from at length lenticularly hardened very low elevations of the otherwise nearly straight margin. Inflorescence 6-10 m. high, the upper third or more rather laxly oblong-paniculate with spreading or recurved branches; pedicels mostly 5-10 mm. long. Flowers yellowish green, 60-65 mm. long, ovary 25-35 mm. long, shorter than the perianth, oblong; tube quickly urceolate 15-20 mm. deep., segments 6-8 by 15-20 mm., much shorter than ovary,

2. Reproduced from 'Agave in the West Indies', by William Trelease.

filaments inserted about the middle of the tube, 40-60 mm. long, twice or thrice as long as the segments. Capsules obovoid-oblong, 25 by 45 mm., slightly stipitate and beaked, seeds 6-8 by 8-10 mm. broad, winged. Freely bulbiferous.

Agave sisalana (Perrine).

Subacaulescent. Leaves finally green and somewhat glossy, at first lightly glaucous and transversely banded on the back, linear-lanceolate, nearly flat, about 10-150 cm., spine dark-brown, somewhat pitted and glossy, tumidly conical or triquetrous, slightly recurved, shallowly round-grooved, near the base, 4-5 by 20-25 mm., not decurrent ; prickles exceptionally nearly as in the last, but typically minute, or almost entirely suppressed. Inflorescence about 6 m. high, the upper half loosely oblong-paniculate ; pedicels 5-10 mm. long. Flowers yellowish-green, 45-60 mm. long, ovary 20-25 mm. long, shorter than the perianth, soon broadly fusiform. ; tube urceolate, 15-20 mm. deep, segments 6-8 by 15-20 mm., a little shorter than the ovary : filaments inserted about the upper third of the tube ; 40-70 or even 80 mm. long, twice or thrice as long as segments. Capsules, when produced, which is rare, oblong, 20-25 by 60 mm. stipitate and beaked, seeds 7 by 10 mm. Freely bulbiferous.

The more prickly form may be known for convenience as var. *armata*.

ON THE INHERITANCE OF THE NUMBER OF TEETH IN THE BRACTS OF GOSSYPIUM.

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INTRODUCTION.

In certain species of Gossypium the bracts are entire. This is said by Watt (1) to be the case in *G. Sturtii*, F.v.M., *G. Robinsoni*, F.v.M., and *G. Harknessi*, Brandg. . According to the same authority, the bracts are entire or slightly toothed in the following species : (1) *G. arboreum*, Linn., and its varieties *neglecta*, Watt, and *assamica*, Watt ; (2) *G. Nanking*, Meyen., and its varieties *rubicunda*, Watt, *Bani*, Watt, and *Roji*, Watt ; (3) *G. obtusifolium*, Roxb. In other species of Gossypium the bracts are more or less deeply lasciniated into from three to twenty teeth, and each pure strain or elementary species has a definite value for the number of teeth to which it breeds true.

This paper contains some general notes on bract teeth, and the results of the examination of the first hybrid generation of certain crosses between types of cotton differing in the number of teeth in the bracts.

(1) 'The Wild and Cultivated Cotton Plants of the World'.

General Notes.

In making counts it is often difficult to decide upon the number of teeth in a given bract. There is no distinct break between 'tooth' and 'no tooth', and all gradations are found between a true tooth and a slight rounded projection. If, however, a projection which is suddenly acuminate, or which terminates in a distinct mucre be termed a tooth, and all others neglected, the results are sound for absolute, as well as for comparative purposes. Countings made by different observers on the same set of bracts gave approximately equal results.

It should be noted that as the plant becomes older, the higher numbers of teeth occur less frequently, and the average number of teeth is lowered. Consequently it is preferable to make counts from plants which have just commenced to flower.

In studying the inheritance of bract teeth, a frequency polygon is constructed or a frequency array compiled for each plant, the number of bracts taken being not less than 150. Fluctuation in the number of teeth of individual bracts is considerable. In each plant, one numerical value is most frequent, and the number of bracts possessing a different number of teeth becomes less as that numerical value diverges more and more from the most frequent value. In a pure strain, all plants have frequency polygons of the same general shape, and usually with the same modal value. In certain cases fluctuation may cause the modal values to sink by a unit. This is easily explainable. A plant may be weakened by aphis attack or cryptogamic disease and thus give a larger proportion of lower numbers. The same result would occur if the plant suffered unduly from bud-shedding, since a considerable number of bracts examined might then be taken from secondary sympodia, and these in general have lower teeth numbers than those from the main fruiting branches. I do not think the occasional divergences met with in these experiments are of genetic significance, provided that the average for the plant falls within the normal range of variation.

Purity of Types Used in the Experiments.

The following kinds of cotton were used in the experiments :—

(a) Sea Island (*G. Barbadense*, var. *maritima*, Watt)
denoted by the letter I.

(b) Southern Cross Upland (*G. hirsutum*, Linn. var.)
denoted by the letter U.

(c) Cauto (*G. brasiliense*, var. *apospermum*, Sprague)
denoted by the letter C.

(d) St. Croix Native, Type 1 (*Gossypium* sp.)
denoted by the letter N.

There will follow from this point the evidence for the purity of each of the above types, after which an account will be given of crosses made between them.

Sea Island. A family of Sea Island, the progeny of a single plant, was grown in 1914-15. Ten plants were grown, of which five were examined for the number of bract teeth. The five plants

received the designations of I 1, I 2, etc. In the next generation twenty plants were grown from I 1, receiving the symbols of I 1·1, I 1·2, etc., and seven plants from I 2—being called I 2·1, I 2·2 etc.

Table I.—Sea Island.

Number of plant.	Frequency of occurrence per 150 of following nos. of bract teeth. 6	7	8	9	10	11	12	13	14	15	Average.
I 1				8	24	68	31	18	1		11·20
I 2		1	1	8	21	60	39	17	3		11·25
I 3			3	23	29	60	26	8	1		10·74
I 4				8	25	55	38	20	4		11·33
I 5	1	1	9	42	50	34	9	4			9 98
Average.	0·2	0·4	2·6	17·8	29·8	55·4	28·6	13·4	1·8		10·90
I 1·1		[illegible]		5	33	55	45	11	1		11·18
I 1·2		2	1	6	34	66	35	4	2		10·95
I 1·3			7	20	30	56	27	10			10·71
I 1·4			2	12	27	69	29	11			10·96
I 1·5			2	20	40	61	21	5	1		10·65
I 1·6		2	3	16	34	54	32	9			10·78
I 1·7			3	20	29	56	32	10			10·83
I 1·8				2	18	63	45	21	1		11·45
I 1·9			2	34	16	50	16	2			10 33
I 1·10				5	31	69	33	12			11·11
I 1·11				8	26	60	40	14	2		11·21
I 1·12			1	7	26	60	43	12	1		11·18
I 1·13			1	11	23	61	38	15	1		11·15
I 1·14			4	10	44	60	32				10·71
I 1·15			6	8	39	59	26	6	6		10·89
I 1·16				10	30	58	44	8			11·07
I 1·17				6	18	70	38	14	2	2	11·33
I 1·18			2	20	40	58	22	6	2		10·69
I 1·19			6	28	30	58	24	4			10·52
I 1·20		2	2	10	30	62	31	10			10·93
Average.		0·3	2·1	12·9	31·4	60 3	32·8	9·2	1·0	0·1	10·93
I 2·1				7	27	66	35	15			11·16
I 2·2			2	8	24	59	39	14	4		11·22
I 2·3				14	42	60	26	8			10·81
I 2·4			1	3	28	52	47	15	4		11·35
I 2·5				6	28	72	34	10			11·09
I 2·6			6	14	38	48	32	12			10·81
I 2·7			6	16	34	52	36	6			10·76
Average.			2·1	8·7	30·6	58·4	35·6	9·3	1·1		11·03

It is clear from Table I that the only plant which is doubtfully of the same gametic constitution as the other plants in respect of the number of bract teeth is plant I 5. Both the average and the modal value of this plant are distinctly lower than the rest. I have, however, included the data in determining the average values for the family. Comparing the figures for plants I 1 and I 2 with those of their progeny, it can scarcely be doubted that Families I 1 and I 2 are breeding true.

SOUTHERN CROSS UPLAND. Two selections U 1, and U 2, were made in 1914-15. Unfortunately no examination was made of these two plants, but data are available for their progeny.

TABLE II.—SOUTHERN CROSS UPLAND.

Number of plant.	FREQUENCY OF OCCURRENCE PER 150 OF FOLLOWING NOS. OF BRACT TEETH. 7	8	9	10	11	12	13	14	15	16	Average.
U. 1·1	2	3	14	28	34	37	20	9	2	1	12·29
U. 1·2	1	4	11	22	43	40	24	5			12·29
U. 1·3			6	20	50	48	26				12·45
U. 1·4	2	8	10	24	37	32	28	7	2		12·27
U. 1·5		5	7	16	29	50	36	7			12·65
U. 1·6	2	6	6	18	34	56	28				12·37
U. 1·7	2	4	8	16	24	42	30	20	4		12·84
U. 1·8	1	10	10	18	35	41	22	10	3		12·37
U. 1·9	1	6	20	26	36	37	21	2	1		12·01
U. 1·10		6	14	32	40	42	16				11·97
U. 1·11	2	5	9	13	33	38	35	8	5	2	12·72
U. 1·12		1	4	18	52	41	18	8	2		12·49
U. 1·13		1	1	21	33	44	29	14	3	1	12·86
U. 1·14	6	8	18	23	27	49	13	3	2	1	11·93
Average.	1·4	5·0	10·1	21·1	36·2	42·9	24·7	6·6	1·6	0·2	12·39
U. 2·1		2	3	8	43	54	23	12	5		12·91
U. 2·2	1	4	7	7	21	58	23	21	5	3	13·10
U. 2·3		2	10	17	33	50	22	11	4	1	12·71
U. 2·4			1	12	28	52	28	24	2		13·12
U. 2·5		2	2	12	26	60	24	12	12		13·13
U. 2·6		4	10	6	24	42	32	16	14	2	13·21
U. 2·7		2	4	4	46	42	36	6	10		13·02
U. 2·8				20	36	28	48	14	4		13·08
U. 2·9		2	6	20	48	42	21	11			13·10
U. 2·10		5	20	26	52	24	16	5	2		11·99
U. 2·11		6	5	21	34	34	30	15	2		12·63
U. 2·12		8	8	24	34	39	23	10	3	1	12·45
Average.	0·8	3·1	6·6	15·0	35·4	43·8	27·4	13·3	5·3	0·6	12·87

From Table II it will be seen that the plants with one exception have the modal value at 12 or 13. It must be said however, that in some of the plants only half the usual number of bracts were examined, and some, owing to severe attacks of aphis were so crippled that they were not examined at the same time as the rest. This, I think, will account for any deviation or unexpected numbers. The evidence presented in the table certainly shows that we have two families of Upland breeding true

CAUTO. Six plants of this variety were grown in 1914-15. The results of an examination of the number of teeth in the bracts are presented in Table III.

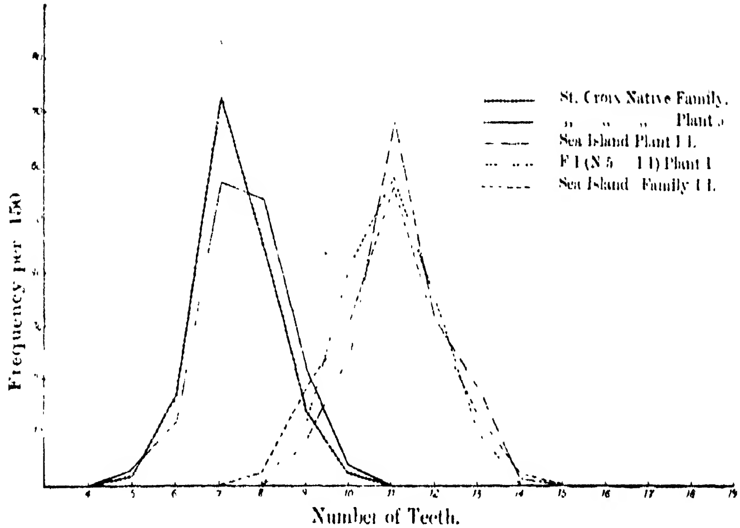

Fig. 1. Sea Island × St. Croix Native.

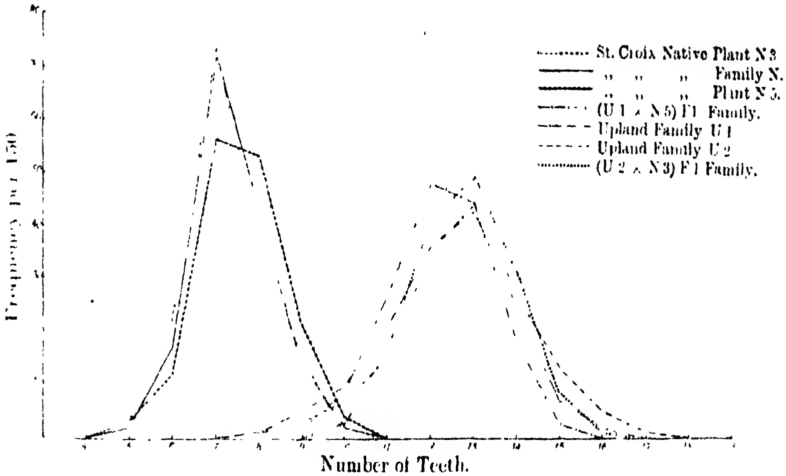

Fig. 2. Southern Cross Upland × St. Croix Native.

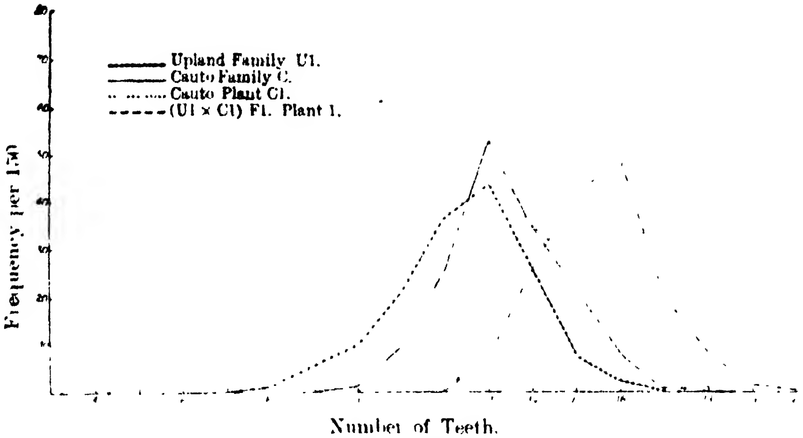

Fig. 3. Southern Cross Upland by Cauto.

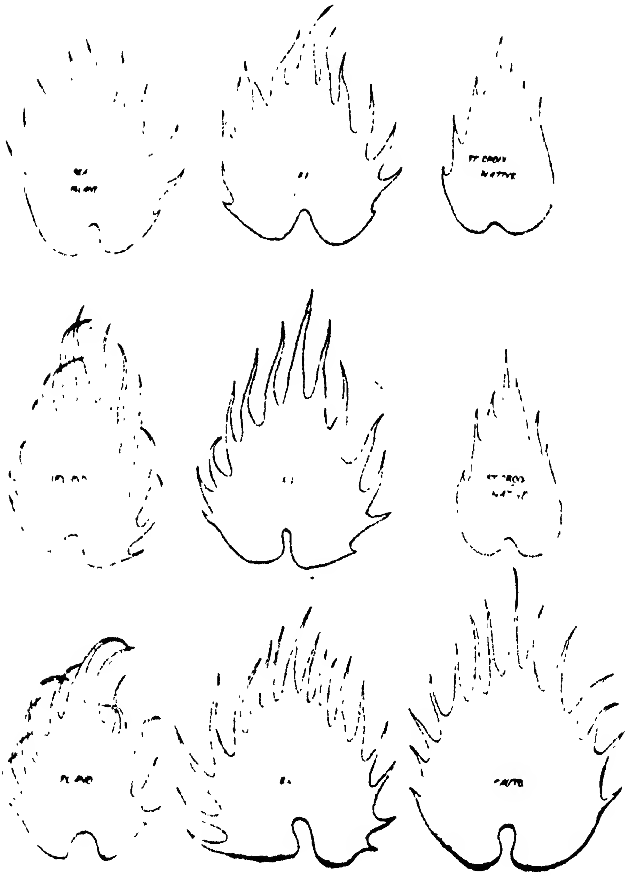

Fig. 4.

Table III.—Cauto.

Number of plant.	Frequency of occurrence per 150 of following nos. of bract teeth. 9	10	11	12	13	14	15	16	17	18	Average.
C. 1		7	20	47	34	26	15	1			13·67
C. 2		11	26	46	40	14	13				13·39
C. 3	1	6	18	53	44	25	3				13·47
C. 4	4	9	26	43	30	25	10	1	1	1	13·46
C. 5	1	14	34	57	21	19	4				13·04
C. 6	2	4	26	63	36	18	1				13·23
Average.	1·3	8·5	25·0	51·5	34·2	21·2	7·7	0·3	0·2	0·2	13·38

All the plants possess a mode at 13. Although the modal value is the same as that for the two families of Upland, the shape of the frequency polygon (see fig. 3) is different, and in general the higher numbers occur more often in Cauto. It must be said also, that the results for the Cauto family were not taken until the plants were well on in the flowering stage, and possibly the values given to higher numbers are too low. Obviously, however, the six plants are of the same gametic composition in regard to this character, and the combination of factors involved is not the same as that of Southern Cross Upland.

ST. CROIX NATIVE, TYPE 1. A family of this variety was grown in 1914-15, and determinations of the number of teeth were made in six plants. The results are given below.

Table IV.—St. Croix Native, Type 1.

Number of plant.	Frequency of occurrence per 150 of following nos. of bract teeth. 4	5	6	7	8	9	10	11	Average.
N. 1		1	15	74	50	9	1		7·36
N. 2			13	78	41	13	2		7·42
N. 3		3	22	73	36	15	1		7·27
N. 4		3	23	73	40	10	1		7·23
N. 5		3	12	56	53	22	4		7·61
N. 6			14	78	42	15	1		7·41
Average.		1·7	16·5	72·0	44·2	11·0	1·7		7·38

These results show that St. Croix Native, Type 1, breeds true to a modal value of 7.

First Hybrid Generation.

Experiment 1. Sea Island by St. Croix Native, Type 1. One cross was made, viz., I 1 × N 5, of which ten plants were grown.

Table V.—Sea Island × St. Croix Native, Type 1.

Number of plant.	Frequency of occurrence per 150 of following nos. of bract teeth. 4	5	6	7	8	9	10	11	12	13	14	Average.
I 1						8	24	68	31	18	1	11·20
N 5		3	12	56	53	22	4					7·67
(I1 × N 5)1						11	41	57	31	10		11·16
2												11·21
3												11·34
4												11·19
5												10·91
6												10·98
7												11·24
8												11 10
9												10·98
10												11·23
Average (F 1)												11·14

A complete frequency array was made only of one plant, the average for the rest being taken from sixty bracts. The modal value for the single plant for which complete figures are available, was 11. From the results it may be concluded that in the first hybrid generation of this cross, the larger number of teeth characteristic of Sea Island is completely dominant over the smaller number of St. Croix Native, Type 1.

Experiment 2. Southern Cross Upland by St. Croix Native, Type 1. The following crosses were made :—

(1) U 1 × N 5.
(2) U 2 × N 3.

Complete data are presented in Table VI, of fourteen F1 1 plants in the former cross, and nine plants in the latter.

TABLE VI.—SOUTHERN CROSS UPLAND × ST. CROIX NATIVE, TYPE 1.

Number of plant.	FREQUENCY OF OCCURRENCE PER 150 OF FOLLOWING NOS. OF BRACT TEETH. 5	6	7	8	9	10	11	12	13	14	15	16	17	Average.
U1 (Fam.)				1	5	10	21	36	13	25	7	2		12·39
N.5.	3	12	56	53	22	4								7·61
U1. × N.5. 1						12	20	11	52	16	6			12·39
2					2	1	28	50	40	16	1			11·80
3					4	6	26	18	56	10				12·17
4						8	10	48	58	22				12·19
5							16	12	56	30	4	2		12·80
6				2	6	20	26	12	32	18	1			11·92
7						6	50	51	21	16				11·96
8					2	8	22	60	38	16	2	2		12·28
9					1	6	23	11	52	19	7	1		12·51
10				4	6	14	20	50	31	10	2			11·79
11						8	26	12	11	26	1			12·44
12						6	20	60	50	11				12·31
13						2	32	14	10	26	6			12·49
14				1	3	22	12	46	27	19				12·57
Average (F 1)				0·5	1·7	8·7	26·7	47·9	43·1	18·3	2·8	0·4		12·26
U2 (Fam.)				1	3	7	15	35	41	27	13	5	1	12·87
N 3	3	22	73	36	15	1								7·27
U2 × N3) 1						6	20	51	42	22	6			12·18
2						8	16	36	11	26	20			12·82
3						2	30	36	12	32	10			12·84
4							10	58	48	30	2	2		12·74
5						2	8	36	56	22	21	2		13·12
6						2	14	26	58	1[illegible]	4	4		13·01
7						2	10	20	64	18	1	0	2	13·12
8							21	56	38	26	4	2		12·57
9						2	20	50	48	28	2			12·57
Average (F 1)						2·7	16·9	11·3	18·8	30·6	8·1	1·1	0·2	12·81

Comparing the F/1 with both parents, we see that both the modal values and averages agree closely with those of the Upland parent, i.e., with the parent possessing the larger number of teeth. The data are presented in the form of frequency polygons in Fig. 2. and it is clear from the F/1 curves that while dominance of the larger number of teeth is pronounced, the curves of the two Upland families agree much more closely. Thus it appears possible to distinguish the heterozygous family from the homozygous in this cross.

Experiment 3. Southern Cross Upland by Canto.

One cross only was made, i.e., U 1 × C 1, of which ten plants were grown. Owing to unfavourable climatic conditions complete results are available for only two plants, the averages for the rest being calculated from sixty bracts.

TABLE VII.—SOUTHERN CROSS UPLAND × CAUTO.

Number of plant.	FREQUENCY OF OCCURRENCE PER 150 OF FOLLOWING NOS. OF BRACT TEETH.													Average.
	8	9	10	11	12	13	14	15	16	17	18	19	20	
U 1 (Fam.)	1	5	10	21	36	43	25	7	2			1		12·39
C. 1.				7	20	47	34	26	15	1				13·67
(U.1 × C1.1)						7	26	41	48	19	8			15·49
2					2	8	21	34	34	32	12	2	2	15·71
3														15·51
4														15·10
5														15·42
6														15·70
7														15·91
8														15·31
9														15·26
10														15·53
Average (F 1)														15·49

We see here that in the two plants for which complete data are given, the modal value is 16 in one case and 15-16 in the other, while the averages for the remaining eight plants are uniformly higher than those of the parents. The view that the gametic constitution of Upland and Cauto is not the same is corroborated by the F/1 results.

SUMMARY AND DISCUSSION.

It has been shown that different varieties of cotton are characterized by differences in the number of teeth in the bracts. It may be stated that frequency polygons of such different forms as those of Sea Island, St. Croix Native, Upland, and Cauto, imply differences in gametic composition in respect of the character.

When crosses are made between types differing in the number of bract teeth, the F/1 in the case of two of the crosses showed complete dominance of the larger number of teeth, but in the third case the F/1 exhibits intensification, and has a larger number of teeth than either of the parents.

Having regard to the fact that certain cottons are known to have bracts from which teeth are absent, it seems fairly clear that it is possible to get at least six homozygous types differing constantly in the number of teeth. Hence at least three factors may be concerned in the production of the tooth value of the cotton possessing the highest number.

ON THE SIGNIFICANCE OF THE RESULTS OBTAINED IN THE DOMINICA MANURIAL EXPERIMENTS WITH CACAO.

BY W. R. DUNLOP,

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The extent to which reliance may be placed upon the statistical results of manurial experiments has been the subject of much discussion in recent years, and it seems that a useful purpose will be served by enquiring into the true significance of the well-known Dominica results. Moreover, the destructive storms that passed over Dominica in 1915 and more particularly in 1916, inflicted damage to the cacao trees in the manurial plots at the Botanic Gardens. A break has therefore occurred in the continuity of these experiments that have now been in progress for fourteen years. In view of this, it seems particularly opportune to review and to discuss the results at the present moment.

For a detailed account of the experiments, the reader is referred to the recent Reports on the Agricultural Department, Dominica, while a study of the conditions obtaining in the experiments from the chemical stand-point appears in the *West Indian Bulletin*, Vol. XIV, pp. 81 to 119. It will answer present purposes to state that the main series has consisted of five plots, each about ¼-acre in area, treated as indicated in the following table, which shows the yields that have been obtained in pounds of cured cacao per acre (calculated).

Dominica Manurial Experiments with Cacao (Main Series).

	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 5.
Year.	No manure.	Phosphate and potash.	Dried blood.	Dried blood, phosphate and potash.	Mulched with grass and leaves.
1902-3.	1,138	1,540	1,494	1,599	1,300
1903-4.	822	1,170	1,131	1,069	1,092
1904-5.	1,009	1,179	1,131	1,418	1,450
1905-6.	1,122	1,105	1,232	1,506	1,724
1906-7.	1,095	1,285	1,134	1,461	1,743
1907-8.	1,354	1,680	1,611	1,709	2,012
1908-9.	1,467	1,745	1,607	1,946	2,017
1909-10.	1,272	1,395	1,361	1,835	2,068
1910-11.	1,288	1,589	1,504	1,879	2,145
1911-12.	1,206	1,466	1,484	1,842	1,953
1912-13.	1,338	1,576	1,764	1,903	2,271
1913-14.	1,017	1,281	1,322	1,599	1,713
1914-15.	1,168	1,519	1,593	1,641	1,947
1915-16.	1,073	1,607	1,514	1,548	1,678

In 1907-8 additional series of experiments were introduced. These are known as Plots 6 to 9 and have received the following treatment : Plot 6, mulched with grass and leaves : Plot 7, cotton-seed meal : Plot 8, no manure : Plot 9, mulched with grass and leaves In 1913-14 two other plots were added : Plot 10, mulched with grass and leaves ; and Plot 11, nitrolim. With the exception of the cotton-seed meal and the nitrolim plots, these additional plots serve to some extent as extra controls for the no-manure and mulched plots in the original series.

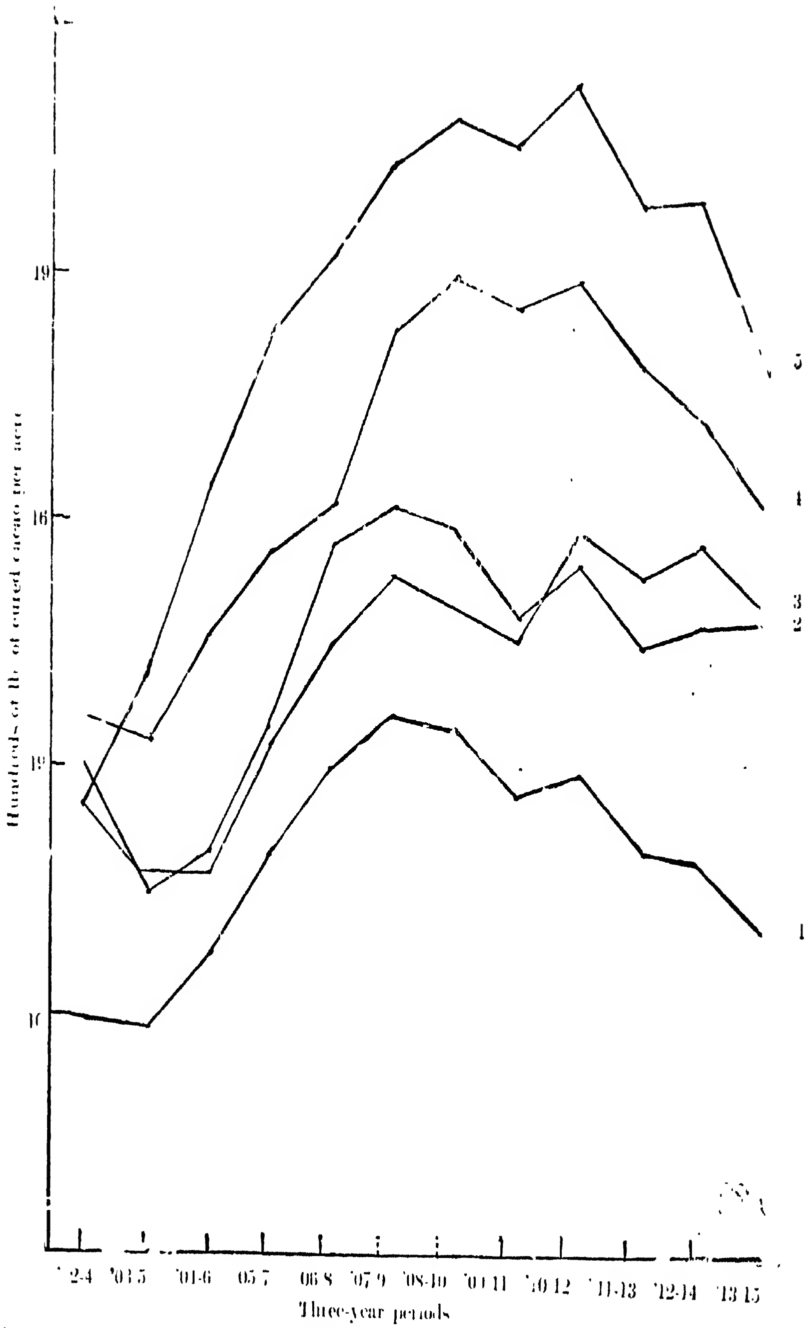
Taking the main series, namely Plots 1 to 5, the general trend of the results can be best appreciated by plotting the results in the form of smoothed curves. This is done by taking the mean for each consecutive three years beginning with the first, second and third year, then the second, third and fourth year, then the third, fourth and fifth year and so on. These means are plotted as shown in the accompanying diagram.

It will be evident that the curves present several striking features. In the first place the benefit derived from mulching, and to a less extent from the application of dried blood and artificials is clearly indicated.

Speaking generally, the yields in the case of several of the plots show a preliminary tendency to fall, followed by a pronounced rise for several years Then in later years a decline took place The rise may be attributed to manurial treatment, and increased care in cultivation which the plots received after the experiments were started. The rise in the case of the control plot must be attributed to increased care. From time to time during the course of the experiments, the trees on the control plot suffered from the need of manure to such an extent that several died and had to be replaced. Under strictly experimental conditions the replacement would not perhaps be considered scientific, but in these experiments the control was kept up because this procedure would be followed by the planter in estate practice. The fact that it was done does not lessen but increases the dependence that can be placed upon observed differences between the treated plots and the control.

The decline in yields from the various plots, which is strikingly illustrated in the diagram, was due principally, it is believed, to the effects of storms High winds were experienced at critical times (e.g. flowering period) in 1912-13, and especially in 1915-16. Also the drop at the second three year period at the beginning of the experiments appears to be due to a storm that passed over the island in 1903. It ought to be noted in this connexion that the plots are not all equally exposed to wind. Nos. 4 and 5 (see table) have suffered worst ; but in spite of that, these two plots have given the most remunerative returns. As a general rule, experience in these experiments has shown the desirability of securing a location for such work where seasonal conditions are uniform. Nevertheless, as will perhaps be more clearly shown later on, these experiments unquestionably indicate the fact that the manuring of cacao is highly remunerative.

DOMINICA MANURIAL EXPERIMENTS WITH CACAO.



No. 1, Control; No. 2 Phosphate and Potash; No. 3, Dried blood; No. 4, Dried blood and Complete Artificials; No. 5, Mulch.

In previous statements of the results of these experiments, however, one important point has not been taken into account. If the curves in the diagram be examined, it will be observed that the yield of the control plot began some 300 lb. of cured cacao per acre below the plots which were to receive treatment. Throughout the course of the experiments this lower 'natural yield' is very evident. Hence in putting forward figures as to the amount of gain derived from manuring, allowance should have been made for this constant difference. This point will be discussed later. Speaking generally, experience would seem to indicate that in manurial experiments with permanent crops, there should be two distinct periods: (a) a period for determining the natural yield of the plots: (b) a period during which the manurial treatment is carried out. The trees should also, as far as possible, be of the same age and be planted the same distance apart.

Even then the exact numerical expression of benefit gained is practically impossible. The increases obtained by mulching in these experiments have been sufficiently great to establish the value of this method of treatment; but apart from yield, there is the general health and vigour of the trees to be considered. Direct inspection only can adequately convince one on this side of the question; but the measurements of the size of treated and untreated lime trees made in Grenada, go a long way to show the physiological benefit derived from mulching. In these experiments it was found that mulching increased the surface area of the trees by 78 per cent.

The following table shows the average monetary gain from manuring over the whole period of the experiments. From what has been said above, these figures are only approximate indications of what may be expected under the conditions of the experiments; they are nevertheless very significant:—

Plot.	Average annual yield of cured cacao, per acre.	Gain in cured cacao over no manure.	Value per acre of increase over no manure at 6*d*. per lb. of cured cacao.		Cost of manuring, per acre.		Gain per acre by manuring.	
	lb.	lb.	s.	d.	s.	d.	s.	d.
1	1,168	...	...		...		...	
2	1,437	251	134	6	45	3	89	3
3	1,419	269	125	6	52	0	73	6
4	1,640	472	236	0	97	3	138	9
5	1,794	626	313	0	80	0	233	0
6	2,075	907	453	6	80	0	363	6
7	1,752	584	292	0	40	0	252	0
8	1,900	...	...		...		...	
9	1,700	789	394	6	80	0	314	6

It will be seen that in the case of the mulched plot (No. 5), there has been an estimated annual net gain per acre of 233s.—a very substantial increase. The value of the cacao, per acre, in the case of the control (No. 1) is 584s., so that the total amount to be secured under conditions of mulching is 817s., less the cost of mulching. In the Trinidad experiments, the average yield of the control plots on the different estates is somewhere in the neighbourhood of 700 lb. cured cacao per acre, worth at 6*d* per lb, 350s. In the British Guiana experiments, the average yield in the case of the controls is about 400 lb. worth, at 6*d*. per lb., 200s. These comparisons show the very high productivity of the mulched plots in Dominica, the mere increase due to mulching being greater than the yield of an ordinary 1-acre of cacao in British Guiana.

It is stated in British Guiana that the sole objection to the use of heavy mulching for cacao is the expense, four years' mulching costing $66 per acre. As a matter of fact it is not the expense but the low return that is the trouble in British Guiana. Sixty-six dollars per acre for four years is $16·50 per acre annually, which compares very favourably with $19·20 per acre per annum in Dominica, where mulching has been shown to be remunerative. But in Dominica, the average annual gain in cured cacao by muching is 626lb. compared with 121lb in British Guiana.

The question arises as to whether allowance ought to be made for the apparent lower natural yield of the control plot (No. 1) in the Dominica experiments. As already pointed out, this yielded at the beginning of the experiments some 300lb. of cured cacao per acre less than the mulched plot before the effect of mulching was felt by the trees. If allowance is made, the increase from mulching will not be 233s. but 233s. - 150s = 83s. If we off-set against this (a) the fact that trees were replaced in the control, and (b) the fact that the mulched plot suffered more from storms, one is disinclined, from a practical stand-point, to make such a rigorous reduction. Moreover, one cannot be certain that the mulching did not affect the trees to the extent of increasing the yield by 300lb. per acre in the first year of the experiments, though it seems unlikely, in view of the fact that in the recently started manurial experiments on limes the mulched plot showed no increased yield over the control until the second year. It is a matter on which it is difficult to come to a decision, and it emphasizes the importance of knowing the natural yield of the plots before the manurial treatment is started.

Taking everything into consideration, one is inclined to the opinion that the monetary gain from mulching in the Dominica experiments may be regarded as not less than 150s. per acre, and the other plots in proportion.

It has been customary in recent years to consider the 'probable error' involved in experimental results. Seeing that in the present series each experiment is represented by a single plot only, no opportunity is afforded for applying the 'probable error' test.

The differences that occur between the yields of each plot in successive years are not errors, but while containing errors, also

contain significant differences due to the treatment of the plots, and the seasonal and other environmental factors to which they are exposed.

In his article in the *West Indian Bulletin* (Vol. XIV), Dr. H A. Tempany has attempted to calculate the probable error for the mulched plot by taking into consideration the mulched plots in the additional series, and arrived at the conclusion that the probable error is in the neighbourhood of 2 or 3 per cent.

The increases obtained by mulching are over six times as great as this, and even allowing for the apparently lower natural yield of the control (No. 1), are over three times as great, so that the results obtained may certainly be regarded as significant. Only in the case of the dried blood alone (Plot 3), and the potash and phosphate alone (Plot 2) is there any doubt as to the remunerative character of manurial treatment.

THE CHARACTERS OF CERTAIN SOILS IN THE AREA DEVASTATED BY THE ERUPTIONS OF THE SOUFRIERE OF ST. VINCENT IN 1902-3.

BY H. A. TEMPANY, D.Sc., F.I.C., F.C.S.,

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During the past few years considerable attention has been devoted in the Government Laboratory for the Leeward Islands to the study of soil problems, notably with reference to conditions obtaining in the tropics.

In this connexion it appeared that it might be of interest if it were possible to enquire into the conditions obtaining when soils are in process of evolution, especially since such an enquiry might tend to throw light on the relative importance of certain of the normal biological activities of the soil.

Excellent opportunity is afforded for the study of such questions in the case of certain soils now in process of evolution in the island of St. Vincent in the area devastated by the eruption of the Soufriere in 1902-3, and the following observations on certain soils taken from that area are put forward as a further contribution to the work already done.

The general effects of the eruption are well known, and are concisely summarized in the following words taken from a paper by Mr. W. N. Sands, published in the *West Indian Bulletin*, Vol. XII, p. 22, and dealing with the return of vegetation to the areas in question :—

'Briefly it might be stated that from May 1902 to March 1903 the volcano was very active and several eruptions of considerable magnitude occurred, accompanied by incandescent avalanches. These avalanches burnt off all the vegetation on the lower slopes on the mountain and the surrounding district, and covered the land with a large deposit of ejecta. The districts which suffered most severely were situated on the west and east slopes of the volcano, and extended from Richmond estate to Windsor Forest on the west, and from Georgetown to Overland Village on the east. The area of these districts is approximately 20 square miles. Within these districts were several flourishing estates whose lands were considered to be the most fertile in the island.'

The effect of such an occurrence in cases in which areas were covered to the depth of several feet with hot volcano sand must have been to have established surface layers which were at the outset completely sterile, and which occupied considerable tracts of country.

During the intervening period of time the process of converting these layers into soil has been in progress, and the effect is seen in the manner in which many of the devastated areas have become partially covered with certain descriptions of vegetation.

The general conditions obtaining in this area in the year 1912 and inferences, are set out in the paper by Mr. W. N. Sands above mentioned, and thereto readers are referred for more detailed information. In relation to questions of soil fertility in this area, Mr. Sands makes the interesting observation, that soon after the eruption, in cases where soils were not covered with too thick a layer of ash, and subsequent cultivation enabled the surface ash covering to be mixed with the underlying soil, crops planted therein grew well; on the other hand, when the layer of ash was too thick to permit of such admixture, practically no growth was made.

The inference was drawn by him that the effect of the hot ash on the underlying soil had been to produce partial sterilization, thereby stimulating certain bacterial processes, and that the result of this is seen when the soil is mixed with the overlying ash. When however the ash was of too great a thickness to permit of its admixture with the underlying soil, no such effect is observed.

Considerable tracts of this latter character exist, which are now becoming retransformed into soil, and it is further obvious that a large proportion of the soils in the West Indian islands of volcanic origin, must have originated from similar deposits in this way, consequently the transformation of such ash deposits must be regarded as representing one of the normal occurrences in the process of soil formation in the West Indies, and as such is worthy of careful study.

With the kind co-operation of Mr. Sands, the writer was furnished early in the year 1916 with three samples of soil from this area of St. Vincent.

Mr. Sands's descriptive notes regarding these samples are as follows :--

Sample No. 1	from Tourama estate :	depth of ejecta	12 inches.
,, No. 2	,, ,, ,,	,, ,, ,,	18 ,,
,, No. 3	,, Orange Hill	,, ,, ,,	14 ,,

The samples consisted of soil entirely formed from ejecta. The manner of taking the samples was as follows. A hole was opened through the ejecta to the former layer of surface soil, and from the side of the hole a vertical section of ejecta was removed, placed in a bag, and numbered. Before opening the hole the vegetation growing on the surface of the ejecta was lightly scraped off, but the roots of it were not touched. The vegetation consisted chiefly of grasses, vines and herbs. The areas from which the samples were derived had not been worked since the eruption of the Soufrière in May 1902.

Each of these samples was subjected to chemical and physical analysis according to the methods usually followed in this Laboratory, while there were, in addition, determined the shrinkage exhibited by the soils on drying, the lime requirement for partial sterilization and for neutralization, the nitrogen-fixing power, the ammonifying power, and the nitrifying power.

As the methods employed in the examination of soils vary somewhat, the various analytical processes utilized are outlined below.

PHYSICAL ANALYSIS. These were performed by the beaker method of Osborne, utilizing the American Standard for the various grades.

CHEMICAL ANALYSIS. This included the determination of the available phosphoric acid and potash by Dyer's method, nitrogen by the Kjeldahl process, and organic carbon and calcium carbonate by the methods described by Watts. (Report on Soils of Dominica, 1902, I. D. A. : also *West Indian Bulletin*, Vol. XII, p. 69.)

The above methods of chemical and physical examination are essentially those employed in the examination of the Soils of Dominica, Montserrat, Nevis and Antigua. (See *West Indian Bulletin*, Vols. VI, X, and XV.)

SHRINKAGE. The method of determining this factor is that given in the *West Indian Bulletin*, Vol. XII, p. 50. It has recently been shown by the writer that the magnitude of the shrinkage observed, serves as an index of the content of colloidal clay in the soil. It may be added that the results of investigations in this connexion will be published shortly.

LIME REQUIREMENTS FOR PARTIAL STERILIZATION AND NEUTRALIZATION. The methods employed were essentially those described by Hutchinson and MacLennan in the *Journal of Agricultural Science*, Vol. VII, Part 1, p. 75.

NITROGEN-FIXING POWER. This is determined by the method given in the *West Indian Bulletin*, Vol. XII; it consists of inoculating 1 gram of soil into sterile Ashby culture solution, incubating at air temperature for twenty-one days, and at the end of that time determining the nitrogen in solution, making allowance for the nitrogen contained in the amount of the soil used for the inoculation.

AMMONIFICATION. This was determined by weighing 100-gram portions of the soil mixed with 2 grams of egg albumen, moistening with water and incubating at air temperature for four days. At the end of that time the ammonia was distilled off with steam into a measured amount of standard acid, and the excess of acid determined by titration.

NITRIFYING POWER. This was determined in a similar way to the ammonifying power, save that the samples were incubated for twenty-one days, the moisture content being made up at the end of each week to its original value. At the end of the incubation period each soil was transferred with 250 c. c. of distilled water to a wide-mouthed jar of 750 c. c. capacity. Two grams of powdered lime were added, and the jar placed in a shaking machine for ten minutes and then allowed to stand until the liquid was clear. When this occurred 100 c. c. were measured out and the nitrates determined by the Griess phenol-sulphenic acid method.

STANDARD OF FERTILITY.

In order to afford a basis of comparison for results, the following data may be quoted as being typical for average arable soils in a satisfactory state of fertility in the Leeward Islands :—

Shrinkage from 1 per cent. to 15 per cent.

Lime requirement for partial sterilization, ·16 to ·32 gram of lime per 100 grams of soil.

Nitrogen-fixing power from 5 to 7 milligrams per gram of soil.

Ammonification from 5 to 9 milligrams of nitrogen per 100 grams of soil per day.

These standards do not differ very greatly from those found by other observers in respect of soils in temperate climates incubated at similar temperatures.

The results of the examination of the soils in question in respect of each of the above quantities are set out in the following pages.

PHYSICAL ANALYSIS.

The physical analyses of the three soils are given below. Owing to misunderstanding, the whole of the available samples were converted into fine earth ; that is to say, particles having a diameter larger than 1 mm. were removed. The soil contained approximately 15 per cent. and 0·20 per cent. of particles larger than 1 mm., and this must be taken into account when reviewing the analyses. The results follow :

Constituent.	Sample 1.	Sample 2.	Sample 3.
Coarse sand	23·1	22·7	17·0
Medium sand	51·2	17·3	54·0
Fine sand	11·7	13·1	5·3
Very fine sand ...	3·9	3·0	5·3
Silt	2·1	3·6	7·6
Fine silt	3·6	7·7	8·3
Clay	0·1	0·1	0·2
Combined water and Organic matter ..	2·1	2·0	2·0
Total	98·1	99·7	99 7

The results indicate that the soils are typically very coarse, the sandy soils containing relatively small amounts of the finer constituents. Physically they resemble, but are distinctly coarser in texture than, the soils encountered at the southern and western end of St. Kitts.

SHRINKAGE.

It is convenient to deal with the results of the shrinkage determination at this point. The results are given below :—

No.	Shrinkage per cent.
1	1·6
2	1·6
3	1·2

These results are of interest, inasmuch as they indicate that during the period which has intervened between the date of deposition of the soils and the present time, a certain amount of colloidal material has been formed.

A factor for calculating approximately the content of colloidal matter from the shrinkage has been worked out in this Laboratory ; the value of this factor is 4·25, and by multiplying the observed shrinkage by it, we obtain an expression for the contents of colloidal clay. In the above cases the results are as follows :—

No.	Colloidal clay, per cent.
1	6·8
2	6 8
3	5·1

J. Stewart* has put forward a view, that the plasticity of clay i. e., its colloidal character, is due to interaction between organic matter and hydrated silicates of aluminium. If this view is correct, the formation of colloids in these soils would appear to be due to the formation and decomposition of organic matter in conjunction with the decomposition of the felspars and other minerals of the original ejecta. On general grounds it would appear that the acquiring of colloidal properties constitutes a very important stage in the conversion of such a layer of volcanic land into soil.

CHEMICAL ANALYSIS.

The results of the chemical analyses of the various soils are given below:—

	Sample 1.	Sample 2.	Sample 3.
Phosphoric acid (soluble in 1 per cent. citric acid solution.) ..	·0186	·0647	·0285
Potash	·0196	·0169	·0068
Carbon dioxide	·0176	nil	·0044
Calcium carbonate ...	·010	nil	·010
Nitrogen	·035	·022	·035
Organic carbon	·870	·460	·440
Humus	1·500	·793	·759
Water at 100° C. .	1·00	·875	·725

In relation to assimilable potash and phosphate, it will be seen that the soils are moderately supplied with these constituents. In this connexion an interesting comparison is possible between the data obtained in these instances and that adduced by Professor d'Albuquerque in the case of the dust which fell in Barbados in 1902. (*West Indian Bulletin*, Vol. II, p. 283.) These data are as follows:—

**Transactions*, 7th International Congress of Applied Chemistry, XV.

The evidence adduced by Stewart in this paper points strongly to the view, that the colloidal character of clay is due to the presence of organic matter. Stewart postulates the existence of definite chemical compounds between organic matter and hydrated silicate of alumina as constituting the colloidal material.

To the writer it appears more probable from considerations of the invariable presence of colloidal matter therein, that the effect is more probably one of peptisation of the finely divided mineral material by the organic matter of the soil.

Potash ... ·016 soluble in 1 per cent. citric acid solution.
Phosphoric anhydride ... ·022 soluble in 1 per cent. citric acid solution.

It must, however, be remembered, that the dust deposited in Barbados was composed of very much smaller particles than that which fell in St. Vincent. Consequently, in determinations such as this, a much larger surface would be exposed to the action of reagents in the case of the Barbados dust as against the St. Vincent ash. It is unfortunate that so far as the writer is aware, no samples of the St. Vincent ash were examined in this respect at the time of the St. Vincent eruption.

The nitrogen contents of all the soils are small, No. 2 showing a smaller nitrogen content than Nos. 1 and 3. This is to be expected owing to the fact that the ash is of considerably greater thickness in the former case.

The content of organic carbon is low in all cases, but is considerably higher in the case of No. 1 than in that of Nos. 2 and 3. This high figure was carefully checked by means of duplicate determinations, but is somewhat difficult to explain. The reason for this result is not obvious, and in other respects the soil does not differ markedly in properties from the other two. In the method of analysis employed, no attempt is made to distinguish between humus and undecomposed organic material; it would seem possible that the result may be due to the presence of undecomposed organic matter in the sample.*

The soil is extremely deficient in calcium carbonate, samples Nos. 1 and 3 showing very minute amounts, while sample No. 2 shows none at all.

Lime Requirement for Neutralization.

The lime requirement for neutralization was determined by means of the methods of Hutchinson and MacLennan, i. e., by treatment with a solution of calcium and carbonate of known strength. In all cases the soils were found to be very distinctly acid. The quantitative results in the case of each determination are given below; they are expressed in terms of the weight of calcium carbonate required to neutralize the acidity in 100 grams of soil.

No.	Grams calcium carbonate required to neutralize the acidity of 100 grams of soil.
1.	·0428
2.	·0304
3.	·0616

* Too much stress should not be laid on the percentage of organic carbon, because in order to get a fair average percentage, a far larger number of samples would have to be examined. The roots of the vegetation and decaying organic matter would not be evenly distributed through the new soil, hence it is quite possible that No. 1 sample was more favourably situated in this respect.

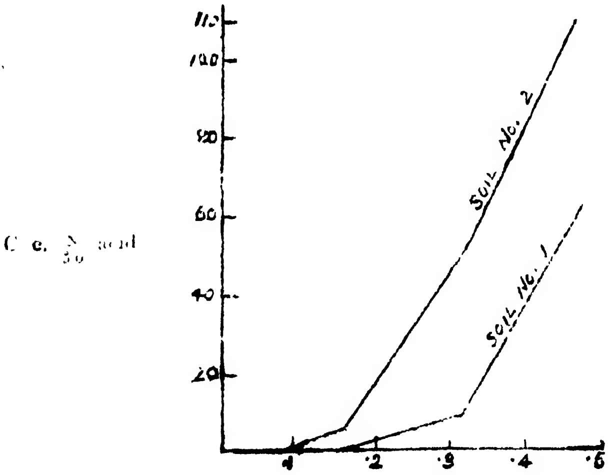
It will be seen that while all the soils are distinctly acid. No. 2 is decidedly less so than Nos. 1 and 3. It seems permissible to infer that in such soils as these, the existence of an acid condition is a normal accompaniment to the process of their formation.

Lime Requirement for Partial Sterilization.

The method employed is that of Hutchinson and MacLennan, and consists in treating equal quantities of soil with calcium oxide in increasing amounts, allowing to stand and subsequently determining the excess alkalinity. The results are held to give an indication of the activity of the putrefactive bacteria in the soil. In the case of these soils it must be remembered that no partial sterilization effect can occur until the existing acidity has been neutralized. The results are given below, the data indicating the number of cubic centimetres of $\frac{N}{50}$ acid required to neutralize the excess alkalinity when increasing amounts of lime are added to 100 grams of soil.

Grams of lime per 100 grams soil.	1 C.c. $\frac{N}{50}$ acid.	2 C. c. $\frac{N}{50}$ acid.	3 C. c. $\frac{N}{50}$ acid.
·08	nil	nil	nil
·16	nil	6·0	nil
·32	7·8	53·4	9·0
·48	62·4	110·1	60·6

The character of the results is best shown when they are plotted in the manner adopted by Hutchinson and MacLennan, the point of partial sterilization being indicated by a change in the direction of the curve termed by them the transition point. The curves given in the case of the two samples are shown below. It will be seen that both curves follow the same general



Grams of lime

direction, and, making allowance for the lower normal acidity of No. 2 compared with No. 1, are closely similar, and show a moderate degree of bacterial activity.

NITROGEN-FIXING POWER.

Examination of the soils by the usual methods shows that the nitrogen-fixing bacteria of the Azotobacter type were present therein.

The results for duplicate determination of the nitrogen-fixing power of each of the three samples is given below, expressed in terms of milligrams of nitrogen per gram of soil :—

No.	Nitrogen fixed per gram of soil.
1	1·05 milligrams
2	0·34 ,,
3	2·23 ,,

All these soils show the existence of nitrogen-fixing power, although when compared with standards found to exist normally in soils in the Leeward Islands Colony, the quantity of nitrogen fixed is relatively very small. No. 2 shows much less nitrogen-fixing power than either Nos. 1 or 3—a result no doubt probably to be attributed to the greater thickness of the ash deposit.

AMMONIFYING POWER.

Examination showed that all of the soils exhibited ammonifying power. The results from the determinations in this connexion are given below, being expressed in terms of milligrams of nitrogen transformed per 100 grams of soil per day :—

No.	Milligrams of nitrogen transformed per 100 grams of soil per day.
1	·75
2	·84
3	1·41

It will be seen that the soils possess a small but appreciable ammonifying power. No. 1 shows a relatively low value compared with No. 3 : the reason for this latter result is not very obvious.

NITRIFICATION.

After incubation for twenty-one days none of these soils showed the development of any nitrates at all ; check determinations performed at the same time with ordinary arable soils showed normal formation of nitrates; one can therefore only conclude that in these soils, in the existing condition, change from ammonia into nitrates cannot take place. Such a result is of great interest and would seem to indicate that plants growing thereon must be taking in their nitrogen in some other form than nitrates—presumably as ammonia.*

* The roots of some of the plants may, however, be deriving nitrogen from the old soil below.

Factors Operating in the Formation of these Soils.

From the foregoing it is obvious that we have to deal with deposits of ash of varying thickness, which have already made considerable progress in the process of conversion into soil. This process has taken place purely by natural means, consequently, by studying the soils and their attendant conditions, one is enabled to form some idea of the means by which this conversion has taken place : while comparison of the above data with those for normal soils permit of one estimating how far the process has proceeded.

Reference to the paper by Mr. Sands, previously alluded to, affords information as to the possible ways in which vegetation has been imported on to these soils and soil organisms reintroduced. In the first place it seems probable that the original soil underlying the ash deposit may not have been completely sterilized, and may have served as a source for the reintroduction of organisms. Food material for these organisms in the shape of organic matter and nitrogen may have been supplied either by the growth of plants from seeds previously existing in the underlying soil, the vitality of which had not been destroyed by the intense heat of the ash fall, by casual transport from adjacent regions which were not affected by the eruption, and to a small extent by nitrogen dissolved by rain. In casual transport, the action of water, of wind, and of living creatures have been probably the principal factors. Mr. Sands's evidence shows that the plants which first make their appearance are usually speaking of a low type ; these are followed in due course by higher forms, and it is doubtless in this way that the organic content of the soil and the dependent biological activities grow up.

General Conclusions.

From a consideration of the foregoing data, it seems probable that the change from sterile ash deposits to fertile soils proceeds slowly in the early stages, but that as the content of organic matter and attendant biological population increase, the change will tend to take place more rapidly, leading ultimately to the production of the soils extremely rich in organic matter, which are characteristic of the forest lands of the smaller West Indian islands.

In relation to the interval of time which must elapse in order to enable this degree of fertility to be obtained, there appears to be evidence to show that a similar set of conditions occurred, though apparently in a less degree of intensity, at the time of the eruption of the St. Vincent Soufrière in 1812. In the ninety years which intervened between that eruption and the one of 1907, a degree of fertility corresponding to that which is met with in other islands in the West Indies seems to have been established. Inferentially, therefore, it would appear that such fertility is, under the conditions observed, capable of being established in a relatively short space of time; it further seems reasonable to suppose that a limit to those accumulations is reached sooner or later under any particular set of conditions, and that when this is obtained, the losses balance the gain. It appears however, that there may be ground for believing that under such circumstances,

the soil conditions prevailing naturally differ markedly from those which are met with under ordinary agricultural conditions.

The biological factors which are chiefly responsible for the changes which take place would seem to consist mainly in the putrefactive bacteria, nitrogen-fixing bacteria, and the ammonifying bacteria. On the other hand, nitrification may be very largely inhibited, while the normal condition of such soils is decidedly acid. Examination of forest soils in Dominica has shown that they normally possess a considerable degree of acidity, notwithstanding the fact that they carry a heavy cover of vegetation. Information as to the intermediate states which exist between those now described and those met with in cases where a heavy cover of forest is present, is lacking; but there seems to be some ground for believing that considerable stores of soil organic matter and nitrogen may be built up under such conditions without the intervention of nitrifying organisms. The subject requires considerable further investigation, and it is not improbable that biological agencies other than those cited may also be at work. These points one must trust to the future to elucidate.

SUMMARY.

1. In the foregoing pages information is given concerning the characters of three samples taken in 1916 from the ash deposits in the Carib country of St. Vincent, which were laid down at the time of the eruption of the St. Vincent Soufrière in 1902.

2. The areas from which the samples were taken have already undergone a fair degree of transformation into soil, and are covered with a growth of vines and bush. The deposits vary in thickness from 11 to 18 inches: the samples taken represent the thickness of the deposits, but do not include any of the original underlying soil.

3. The samples were submitted to physical and chemical analyses, while the shrinkage, lime requirement, nitrogen-fixing power, ammonifying power, and nitrifying power were also investigated.

4. Physically the soils were found to consist of coarse sandy types; they showed shrinkages ranging between 1 and 2 per cent., thereby indicating the formation of a certain amount of colloidal material.

5. Chemically the soils showed small contents of organic carbon and nitrogen; they were extremely deficient in calcium carbonate: they showed the presence of moderate amounts of available phosphoric acid and potash.

6. Characteristically the soils all possessed an appreciable degree of acidity, as evidenced by the lime requirement for neutralization.

7. The biological activity of the soils was found to be as follows: the value for the figure for partial sterilization indicated the existence of a moderate activity in respect of putrefactive bacteria. Nitrogen-fixing organisms of the Azotobacter type were found to be present, and the soils showed small, but appreci

able, nitrogen-fixing power. The soils also possessed appreciable ammonifying power, but were completely deficient in nitrifying power.

8. During the fourteen years which have intervened between the eruption and the date on which the samples were taken, considerable progress has been made in the conversion of the sterile ash deposits then laid down, into fertile soil.

9. The means by which this change has been accomplished are briefly discussed, and the relationships indicated thereby to the origin of the very rich soils characteristic of the forest lands of the West Indian islands, are considered. The acid condition of the soil and the absence of nitrification are alluded to, and the possibility of such soils being built up without the active intervention of nitrifying organisms is indicated.

In conclusion I desire to express my thanks to the following: to Mr. W. N. Sands, Agricultural Superintendent, St. Vincent, for assistance in the taking of the samples and supplying information concerning them; to Mr. F. L. Harrison, B.A., B.Sc., Science Master at the Antigua Grammar School, for the performance of a considerable share of the analytical work; and to Mr. E. F. Shepherd, Junior Assistant at the Laboratory, for help in the same connexion.

THE 'GALL PATCHES' IN ANTIGUA SOILS.

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In a paper on the Soils of Antigua published in the *West Indian Bulletin*, Vol. XV, No. 2, attention was directed by the writer to the occurrence in the limestone district of Antigua of localized areas which are unable to grow satisfactory crops of sugar-cane, commonly known among planters as 'Gall Patches'.

It was pointed out that these patches are usually roughly circular in outline; that in area they do not generally exceed $\frac{1}{10}$-acre (although larger patches are occasionally met with); and that canes planted thereon usually assume a characteristically etiolated* appearance, and frequently die out after a time.

Practically all crops show etiolation when grown on these patches, but some plants, notably cotton, are much less susceptible to unfavourable influence than is sugar-cane, and are capable of being grown thereon with fair success.

In the paper in question, data for the chemical and physical examination of soils from two typical gall patches were adduced.

* It has been customary to use the term 'etiolated' in connection with plants growing on gall patches, but, strictly speaking, the correct term to employ would appear to be 'chlorotic'.—*Ed.* W.I.B.

It was shown that in physical composition they exhibited no apparent difference from the ordinary run of soils encountered in the limestone area, while chemical examination revealed that the most striking feature was the relatively very high content of potash and soda soluble in 20 per cent. hydrochloric acid at boiling temperature.

Definite evidence was further brought forward to show that gall patches were not due, as had been suggested, to the presence of excessive amounts of lime salts in the soil, inasmuch as in the case of the soils from the two gall patches examined, it was shown that the actual content of calcium carbonate amounted only to 3·55 per cent. and 2·86 per cent., respectively.

The suggestion was put forward that gall patches might represent points at which saline material had been brought to the surface from deeper levels, and that the effect observed might be due to the accumulation of these saline materials in the surface layers, combined with the formation therefrom of alkaline carbonates by reason of interaction between calcium carbonate contained in the soil and subsoil, and sodium chloride dissolved in the soil waters.

On the suggestion of a planter working estates in the vicinity of the island in which gall patches are of frequent occurrence, it was decided early in 1916 to follow up the work already performed, and to attempt definitely to settle the question of the origin of these areas.

For this purpose investigations were made on two large gall patches situated on an estate in the north-eastern district of the island. The investigations in question comprised: (1) examination of the soils by chemical methods; (2) culture experiments in tubs with soil taken from a gall patch; (3) examination of canes growing on gall patches and showing characteristic etiolation: and (4) examination of the soil in respect of certain biological characters.

In investigating the chemical characteristics of these gall patches, comparisons were effected between the soils of the gall patches themselves and those from the regions immediately adjoining them, which were bearing luxuriant crops of cane at the time the samples were taken. The samples were in all cases drawn by means of a soil auger to a depth of 12 inches, and in each case a number of individual samples were taken and afterwards bulked.

The soils were in the first place examined in respect of the contents of nitrogen, organic carbon, and calcium carbonate. The results are given below: –

GALL PATCH 'A'.

Constituent.	Soil from gall patch.	Soil adjoining gall patch.
Nitrogen ...	0·16 per cent.	0·17 per cent.
Organic carbon ...	2·04 ,, ,,	2·32 ,, ,,
Equivalent humus	3·52 ,, ,,	4·00 ,, ,,
Calcium carbonate	18·2 ,, ,,	15·4 ,, ,,

GALL PATCH 'B'.

Constituent.	Soil from gall patch.	Soil adjoining gall patch.
Nitrogen	0·14 per cent.	0·15 per cent.
Organic carbon .	2·83 " "	3·52 " "
Equivalent humus	4·88 " "	6·07 " "
Calcium carbonate	13·4 " "	14·8 " "

It will be observed that in respect of the above factors, the gall patch soils do not show any marked differences from those adjoining the gall patches and producing good crops of cane. It is however to be noted, that both in the case of nitrogen and organic carbon the soils adjoining the gall patches contain somewhat larger amounts than do the gall patches themselves. The results further give conclusive evidence that the effect is in no way directly attributable to excessive amounts of calcium carbonate.

In relation to both gall patches 'A' and 'B', investigation was made of the soil solution obtained by extracting known quantities of soil with successive amounts of distilled water.

It was found that this method of extraction constituted the only satisfactory way of determining the total amounts of soluble salts, owing to the fact that the soils possessed considerable adsorptive power, and a system of single extraction gave amounts too small to be capable of accurate determination.

To exemplify this, the following data may be quoted: 100 grams of soil from gall patches 'A' and 'B', and equal amounts from the samples taken from the adjoining areas were extracted once with hot distilled water for six hours on the water bath with constant shaking. At the end of that time the per cent. of soluble matter extracted from the soil was found to be as follows, the results being expressed as a percentage of the soil itself:—

	Gall Patch 'A'.		Gall Patch 'B'.	
	Soil from gall patch.	Soil adjoining gall patch.	Soil from gall patch.	Soil adjoining gall patch.
Total soluble matter, per cent.	·12	·13	·12	·12

In contrast to these figures the following data give the values obtained for the total soluble matter when extraction was performed in the cold by successive quantities of distilled water for a period of a week, as stated above:—

	Gall Patch 'A'.		Gall Patch 'B'.	
	Soil from gall patch.	Soil adjoining gall patch.	Soil from gall patch.	Soil adjoining gall patch.
Total soluble matter, per cent. on soil	0·48	·32	0·31	0·25

It will be seen that in both these cases the gall patch soils show a considerably higher content of soluble matter than do the soils adjoining the gall patch. Further information was obtained in this connexion by approximate determination of the composition of the dissolved mineral matter in the case of the soil solution from gall patch 'B' and from the adjoining region of this gall patch.

Soil Solution.—Gall Patch 'B'.

Constituent.	Soil from gall patch, per cent. on soil.	Soil adjoining gall patch, per cent. on soil.
Calcium carbonate	0·57	·102
Sodium carbonate	·110	·048
Sodium chloride ...	·012	·016

It will be seen that the most striking difference consists in the large amount of soluble sodium carbonate contained in the soil solution from the gall patch, thus bearing out previous ideas in this connexion.

In order to obtain further information as to the character of the soil solution likely to be obtained from normal soils in this region of the island, a similar extraction was performed on a sample of soil taken from the same district which showed no evidences of gall patch, and which had borne a satisfactory record in respect of crop production for many years past. The data are given below :—

Total soluble solids	0·356 per cent. on soil.
Calcium carbonate	0·120 .. ,, ,, ..
Sodium chloride	0·071 .. ,, ...
Sodium carbonate	0·042 .. .. ,, ..

From the foregoing it would appear probable that the soluble sodium carbonate in the soil as determined in this way may reach as high as 0·05 per cent. without ill effects being seen.

To check these deductions, the attempt was made to ascertain the effect of the removal of this soluble matter on plant growth. Accordingly an experiment was carried out in which canes were grown in tubs containing soil from gall patch 'A'. The tubs were set up as follows: the first tub was provided with a thorough system of drainage at the bottom and filled with soil from the gall patch; the soil in the tub was systematically flooded with rain-water twice a day for a period of one week; such a form of treatment corresponds fairly closely to the extraction as performed in the laboratory, the results of which have already been recorded, and by means of it amounts of soluble matter may be presumed to have been removed approximately equal to those taken out in the laboratory extraction. The second tub was not provided with drainage, and was filled with soil from the gall patch without any treatment. In both tubs three cane plants were planted, the variety selected being B. 4596.

The moisture content of both tubs was carefully controlled, rain-water being added as required to maintain the optimum moisture condition. Arrangements were made for putting the

tubs under shelter at night and during times when rain was falling ; at other times both tubs were exposed to direct sunlight.

During the early stages of growth no marked difference was seen between the two tubs, except that the canes in the untreated tub did not germinate quite so early as those in the treated tub. Otherwise, growth in both cases was quite normal.

After the first four weeks however, the canes in the untreated tub began to show distinct signs of etiolation, which became quite marked by the end of the second month. At the end of four months the canes in the treated tub were making normal growth, while the canes in the untreated tub were markedly etiolated and dying out, showing the appearances characteristically seen in the case of canes grown on gall patches in the field. The appearances of the tubs after four months' growth are illustrated in the accompanying photograph.

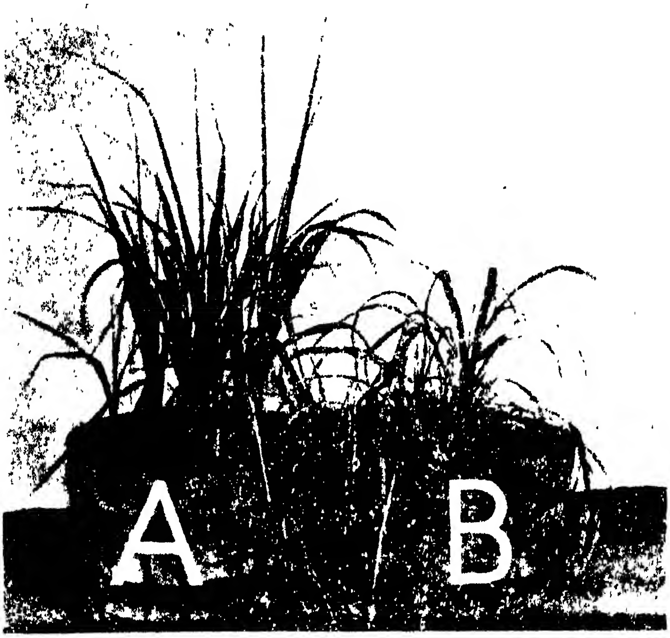

FIG 1.

A. Gall patch soil washed out with successive floodings of rain-water for one week.
B. Untreated gall patch soil.

Further corroborative information on the subject was obtained from the chemical examination of the leaves of canes growing on gall patches, and confirmation of the results already adduced is given by the following partial analyses of leaves taken from etiolated canes growing on gall patch 'B' as compared with the leaves from healthy canes growing on the adjoining land.

The results have been calculated to the water free basis.

Constituent.	Leaves from gall patch 'B'.	Leaves from healthy canes adjoining gall patch 'B'.
Nitrogen	0·79	0·80
Ash	12·4	9·4
Organic matter ...	87·6	90·2
Chlorine	1·77	1·31
Phosphoric acid ...	0·45	0·22
Lime	0·77	0·77
Soda	2·20	0·77
Potash	3·14	1·89
Magnesium ...	0·53	0·08

Examination of the above data shows that the ash content of the leaves of the canes grown on the gall patch is considerably greater than that of the leaves of the normal cane ; the difference is especially marked when one compares the content of potash and soda of the leaves from the canes growing on the gall patch, containing nearly three times as much soda as do those of the normal cane plant. These results give valuable independent corroboration of the conclusions already arrived at.

It is of some interest to record that a moderately well-grown cane showing characteristic etiolation was crushed, and the juice compared with that of a normal healthy cane of about the same age growing on the adjoining area. The results are as follows :—

	Juice of etiolated cane.	Juice of normal cane.
Total solids ...	1·363 lb. per gall.	1·755 lb. per gall.
Sucrose ..	0·939	1·235 .. .. ..
Glucose ...	0·210 „ .. „	0·201 „ .. „
Glucose ratio ...	22·1 .. .. „	16·3 „ „ ..
Purity ...	68·9	70·4

As is to be expected, the abnormal soil conditions appear to have seriously interfered with metabolism.

In relation to the bacterial activities of gall patch soils, some investigations were made into the question of the lime requirement for partial sterilization, the significance of which as a measure of biological activity has been called attention to in another communication in this number of the *Bulletin*. Measure-

ments of this description were carried out on the soil from gall patch 'B', and on the soil bearing healthy canes adjoining the gall patch, and also on treated and untreated soils from gall patch 'A' in the tub experiments already described.

The results are given below :—

Lime added per 100 grams soil.	Soil from gall patch 'B'. (1) c.c. $\frac{N}{50}$ acid required for neutralization.	Soil adjoining gall patch 'B'. (2) c.c. $\frac{N}{50}$ acid required for neutralization.	Untreated soil from gall patch 'A'. (3) c.c. $\frac{N}{50}$ acid required for neutralization.	Soil from gall patch 'A' washed with rain-water. (4) c.c. $\frac{N}{50}$ acid required for neutralization.
·16	17·4	10·8	7·2	4·8
·32	31·2	30·6	..	12·0
·48	49·5	48·6	43·2	63·0
·64	...	67·8	58·2	90·6

The construction of curves has shown that in the case of No. 1 in the above table, the curve shows no evidence of the existence of a transition point; No. 2 shows a distinct transition point when ·16 gram of lime has been added, No. 3 shows some evidence of a transition point but less marked than No. 2, while No. 4 shows a very marked transition point.

The determinations were performed on Nos. 3 and 4 the same months after the soils had been placed in tubs, and this may have influenced the effect in the case of No. 3.

In any case the results appear to indicate that the presence of excessive amounts of alkali carbonates in the soil has the effect of retarding the action of putrefactive bacteria responsible for the decay of humus.

Measurements were also made of the nitrogen-fixing power of soils from gall patch 'A' and the soil adjoining, by the usual method of inoculation into sterile Ashby culture solution, incubation for eighteen days and subsequent determination of the nitrogen content of the inoculated solution. The results are as follows; in both cases they are the means of duplicate determinations :—

	Milligrams of nitrogen fixed per gram of soil.
Gall patch 'A'	6·48
Soil adjoining gall patch 'A'	4·74

It will be seen that in this case the presence of alkali carbonates in the soil does not appear to exert any inhibiting effect on the activity of Azotobacter.

The foregoing data appear to show with reasonable clearness, that the effect in question is due to the presence in the soil of

excessive quantities of alkali carbonates. The origin of these is, as has been stated, probably due to reaction between saline mineral matter brought from lower levels to the surface soil with calcium carbonate contained in the soil and the underlying strata. The existence of these saline strata interbedded with the rocks of certain levels in Antigua has been demonstrated in the paper by the writer on 'The Ground Waters of Antigua' (*West Indian Bulletin*, Vol. XIV, p. 281), where it is also shown that these saliniferous beds outcrop along a line running from north-west to south-east of the island, and dip under the limestone strata of the north eastern area. The reason for the localization of these alkali deposits may be due to breaks in the continuity of the impervious bottom layer separating the calcareous from the underlying non-calcareous strata; or, on the other hand, it may be attributable to specific localization dependent on variations in the physical texture and chemical composition of the soil and underlying rocks.

While the cause of gall patches may be regarded as elucidated with a fair degree of clearness, their removal or amelioration remains a problem presenting many difficulties. The installation of a large-scale system of irrigation might possibly enable the problem to be dealt with to some extent, while it is also possible that some improvement is capable of being effected by means of applications of calcium sulphate. On the other hand, under present conditions, the outlook for improvement cannot be regarded as very hopeful.

SUMMARY.

In the foregoing paper the origin of areas which are incapable of producing satisfactory crops of cane in the limestone district of Antigua is discussed.

2. The question had already been considered in a paper by the writer on the soils of Antigua, in which it was shown that the effect in question was not due to physical abnormalities or to the presence of excessive amounts of calcium carbonate in the soil. Chemical analyses of such soils show that they contain large amounts of alkali soluble in hydrochloric acid. The suggestion was then put forward that the result was probably due to the presence of sodium carbonate in the soil.

3. Further investigations have fully confirmed this view. These investigations have comprised examinations of the water extract from gall patch soils, the cultivation of canes in tubs containing gall patch soils, which in the one case was untreated, and in the other had been thoroughly washed out with rain-water; the examination of the leaves of etiolated cane plants growing on gall patches in comparison with leaves from healthy canes; and the investigation of certain biological activities of gall patch soils.

4. The results indicate clearly that the effect in question is due to the presence of sodium carbonate in the soil. The origin of this sodium carbonate is attributed to interaction between the calcium carbonate and the sodium chloride dissolved in soil water, and brought up from saliniferous deposits at deeper levels.

A NOTE ON THE LIME REQUIREMENT OF SOILS FOR PARTIAL STERILIZATION PURPOSES.

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H. B. Hutchinson and K. MacLennan have recently shown that one of the results of the application of caustic lime to soils, is the production of a partial sterilization effect analogous to the action produced by heat and antiseptics.

In a recent paper published in the *Journal of Agricultural Science** they have adduced a method of measuring in the Laboratory the amount of lime which requires to be added to any given soil in order to produce the effect in question, and have correlated the results thus obtained with observations made in this respect on the same soils in the field.

The laboratory method of Hutchinson and MacLennan as described by them, consists essentially as follows:—

'The method originally adopted, and to which we have adhered throughout, is based on the determination of the minimum amount of lime required to render the soil water distinctly alkaline, and is as follows: 100 gram lots of the air-dry soil to be tested are placed in bottles of about 250 c.c. capacity; according to the character of the soil (whether poor or rich, light or heavy), a number of dressings of calcium oxide are then made, rising by increments of 0·1 gram to 1·0 per cent., or increments of 0·2 gram to 2·0 per cent., of the weight of the soil. Sufficient water (50 c.c.) is added to moisten the soil; the bottles are then tightly corked and shaken for a few seconds at intervals for a definite period. This period is generally twenty four hours, but actual comparisons have shown, that the amount of change between four and twenty-four hours is only slight. At the end of this time the contents of the bottles are then transferred to, and washed in, a Buchner funnel with a further 200 c.c. of water; the whole of the filtrate is then titrated with $\frac{N}{1}$ acid, using phenol phthalein as indicator.

'Within the range of applications made in the above manner, it will generally be found that a point is reached where the reaction of the filtrate is distinctly alkaline, and the results of other investigations have shown that where the alkalinity is such that 5-10 c.c.† of $\frac{N}{10}$ acid are required to neutralize the whole of the filtrate, this may be taken as the limit to which calcium oxide must be applied to the soil in order to produce the best results.'

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* *Journal of Agricultural Science*, Vol. VII, Part I, p. 75.

† In view of the fact that in Dr. Tempany's method, described later, 100 c.c. of solution equivalent to 16·33 grams of soil is titrated against $\frac{N}{50}$ acid, it follows that the range in that method corresponding to the figures given by Hutchinson and MacLennan is 4-8 c.c.

During the past twelve months a number of observations have been conducted on similar lines in the Government Laboratory for the Leeward Islands. After a certain amount of experience of the method as described by Hutchinson and MacLennan, one or two difficulties were encountered in applying it under laboratory conditions, and certain modifications in manipulatory details were introduced.

The difficulties consisted essentially in the filtration and washing of the soils, which, in the method as originally described, proved to be almost impossible of satisfactory attainment, especially in the case of heavy soils from the Leeward Islands.

The method as finally adopted, was as follows:—

Portions consisting of 50 grams each of air-dry soil were placed in wide-mouthed stoppered bottles of capacity of about 600 c.c. To each of these lots of soil were added weighed amounts of lime, increasing in quantity from 0·1 to 0·5 gram CaO, the lime being thoroughly mixed with the soil. To each lot of soil treated in this way 25 c.c. of water were added, the stoppers of the jars inserted, the jars thoroughly shaken until the contents had become more or less uniformly distributed over the sides and bottom, and then allowed to stand for eighteen hours.

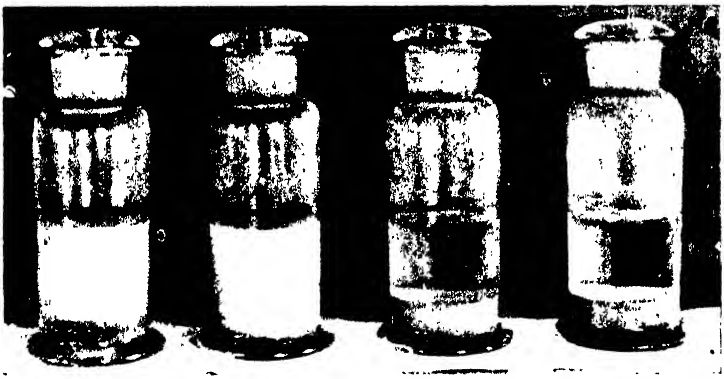

FIG. 1.

Grams lime per 100 grams soil.

0·16 0·32 0·48 0·64

Illustrating the effect of the addition of increasing amounts of lime on the flocculation of the suspended clay

At the end of that time 275 c. c. additional water were added to the contents of each jar, and the jars allowed to stand until the suspended soil had settled out; 100 c. c. of the supernatant liquid were then pipetted off and titrated against $\frac{N}{50}$ hydrochloric acid, using phenol phthalein as indicator.

The results are plotted in the form of a curve, the number of c. c. of $\frac{N}{50}$ acid required to produce neutrality forming one ordinate, and the corresponding weight of lime added, the other. The point at which partial sterilization occurs is indicated by a change in the slope of the curves, and has been termed by Hutchinson and MacLennan, the transition point.

These workers have further pointed out that in the method as worked by them, indication of the occurrence of the transition point could be obtained from the degree of flocculation of the soil compounds suspended in the soil water, and was susceptible of measurement from the time required for the filtration of a definite amount of wash water.

This was borne out in results obtained by the modified method, the point at which partial sterilization occurs being indicated by the almost complete subsidence of all suspended material after two hours' standing; when, on the other hand, the lime added is insufficient to produce partial sterilization, flocculation does not occur, and the supernatant liquid remains turbid. This is shown in the accompanying photograph, Figure 1.

The results obtained in the case of fourteen soils from various parts of the Leeward Islands are given in the following table, the results for Nos. 1, 9, and 10, being also displayed graphically in Figure 2.

In addition to the numerical results, the degree of turbidity of the supernatant liquid is also indicated in the majority of cases with the object of showing how far the transition point is capable of being gauged from the appearance in this connexion.

In the table

V. T.	denotes	Very turbid
T.	,,	Turbid
S. T.	,,	Slightly turbid
C.	,,	Clear

Grams CaO per 100 grams soil.	No. 1 c.c. $\frac{N}{50}$ acid.*	Turbidity.	No 2 c.c. $\frac{N}{50}$ acid.	Turbidity.	No. 3 c.c. $\frac{N}{50}$ acid.	Turbidity.
·16	6·6	V.T.	3·6	T.	7·8	T.
·32	36·0	S.T.	27·0	C.	23·4	S.T.
·48	71·4	C.	48·6	C.	48·0	C.
·64	112·3	C.	76·2	C.	79·2	C.

*Number of c.c. $\frac{N}{50}$ acid required to neutralize 100 c.c. of filtrate equivalent to 16·33 grams of soil used.

Grams CaO per 100 grams soil.	No. 4 c.c. $\frac{N}{50}$ acid.	Turbidity.	No. 5 c.c. $\frac{N}{50}$ acid.	Turbidity.	No. 6 c.c. $\frac{N}{50}$ acid.	Turbidity.	No. 7 c.c. $\frac{N}{50}$ acid.	Turbidity.
·16	10·8	T.	nil	T.	8·4	T·	6·6	V.T.
·32	30·6	S.T.	33·6	S.T.	39·6	S·T·	13·0	T.
·48	48·6	C.	75·6	C·	66·2	C.	34·8	C.
·64	67·8	C.	135·0	C·	91·8	C.	66·0	C.

Grams CaO per 100 grams soil.	No. 8 c.c. $\frac{N}{50}$ acid.	Turbidity.	No. 9 c.c. $\frac{N}{50}$ acid	Turbidity.	No. 10 c.c. $\frac{N}{50}$ acid	Turbidity.	No. 11 c.c. $\frac{N}{50}$ acid.	Turbidity.
·16	nil	V.T.	nil	T.	5·4	V.T.	9·0	V.T.
·32	9·5	T.	nil	S.T.	9·6	T.	...	T.
·48	35·0	C.	10·2	C.	18·6	S.T.	27·6	S.T.
·64	85·0	C.	25·8	C.	30·0	C.	55·8	C.

Grams CaO per 100 grams soil.	No. 12 c.c. $\frac{N}{50}$ acid.	Turbidity.	No. 13 c.c. $\frac{N}{50}$ acid.	Turbidity.	No. 14 c.c. $\frac{N}{50}$ acid.	Turbidity.
·16	nil	V.T.	5·0	T.	8·4	V.T.
·32	30·0	T.	20·0	C.	12·0	V.T.
·48	59·4	C.	35·0	C.	28·4	T.
·64	115·2	C.	95·0	C.	58·2	C.

In the above results Nos. 1 to 6 represent soil samples taken from cane and cotton fields in Antigua and St. Kitts in good heart, and producing satisfactory crops of cane or cotton. No. 7 is from a cane field in Antigua in which canes were not doing well. No. 8 is from Nevis. Nos. 9, 10, 11, 12, and 13, are soils from the Botanic and Experiment Stations in Antigua, Montserrat, and St. Kitts, which had probably been highly manured from time to time, while No. 14 is from copse land in Antigua, which had not been under cultivation for at least fifty years.

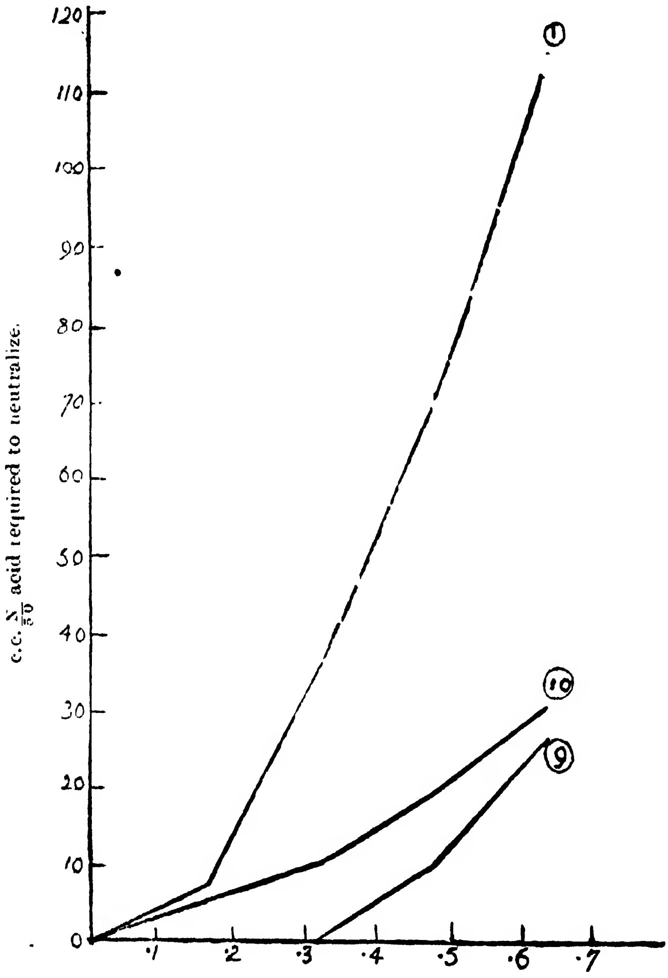

Fig. 2.

Selected curves showing Transition Point in partial sterilization.

Examination of the figures and curves for Nos. 1, 9, and 10, will show that the transition point is reached in the case of Nos. 1 to 6 when an application of ·16 gram of lime per 100 grams of soil has been made; in the case of the other examples,

the amount of lime requiring to be added to effect partial sterilization is greater than this. Comparison of the numerical data with the results obtained in respect of turbidity shows that this factor gives a reliable indication of the end point of the reaction in almost all cases.

The results are similar in general character to those adduced by Hutchinson and MacLennan, and generally corroborate them.

These workers have shown that a close correlation can be observed between the laboratory results and the data obtained from application of the theoretically indicated amounts of lime required to produce partial sterilization in the field. Experiments are now in progress designed to ascertain the correlation between laboratory results and tub experiments, the results of which will be reported in due course.

In general, the method appears likely to possess special value as a means of obtaining information regarding the biological activity of soils in certain directions.

The rationale underlying the process is not very clear, but would seem to be that when insufficient lime has been added to the soil to effect partial sterilization, the action of the putrefactive bacteria of the soil resulting in the liberation of carbon dioxide leads to the neutralization of a portion of the lime which has been added to the soil; when, on the other hand, sufficient lime has been added to the soil to effect partial sterilization, liberation of carbon dioxide is inhibited.

Calculation of the total amount of lime present in solution at the different points will show that it is always considerably below the total amount added to the soil. This is no doubt due to adsorption of lime by soil colloids, since the increase in alkalinity, especially after the transition point has been reached, indicates the existence of a linear relationship between the total amount of lime added to the soil and the quantity passing into solution. The actual slope of the curve will vary in individual cases, and gives an indication of the adsorption power of the soil.

In conclusion it may be added, that when the end point is judged by the turbidity, the method presents no difficulties in its performance by any intelligent person, and appears to offer considerable possibilities of usefulness as an easy means of judging the condition of soils in practice, once the necessary standards have been erected.

From the foregoing results it appears that the soils examined require the following quantities of quicklime per acre to effect partial sterilization to a depth of 1 foot (=3,500,000 lb. soil).

Soil No.	Tons of quicklime.	Soil No.	Tons of quicklime.
1	2·5	8	5·0
2	2·5	9	7·5
3	2·5	10	5·0
4	2·5	11	5·0
5	2·5	12	2·5
6	2·5	13	2·5
7	2·5	14	2·5

SUMMARY.

1. The results are described in detail of the examination of fourteen soils from the Leeward Islands in respect of the lime requirement for partial sterilization.

2. The method followed is that described by Hutchinson and MacLennan with some modifications, the most important of which consists in a simple device for ascertaining the end point by means of the relative turbidity of the supernatant soil water.

3. The method appears to be capable of affording valuable information respecting the biological activity of certain soils.

4. In the concluding section the rationale of the process is briefly discussed, together with the probable connexion existing between the actual amount of lime passing into solution and the absorption due to soil colloids.

THE FUNGI OF INTERNAL BOLL DISEASE.

BY W. NOWELL, D.I.C.,

Mycologist on the Staff of the Imperial Department of Agriculture for the West Indies.

The publication by Mr. Albert Schneider[5] of an account of a fungus found in tomato fruits and closely resembling *Nematospora Coryli*, Peglion, makes it desirable to give a preliminary account of certain fungi, including a species closely resembling that described by Schneider, which occur in green cotton bolls in the West Indies. The forms referred to are four in number, and are connected by certain special features which seem to imply a close relationship between them. Taken singly these organisms are difficult to place in the fungus groups at present recognized ; and when taken as a series the difficulties are increased. It would seem that the facts regarding them will be of considerable importance in future discussions of the taxonomy of the simpler fungi.

The necessity, in these circumstances, of making the observations as complete as possible, and of referring fully to the literature bearing on the subject—a slow process at present owing to the difficulties of communication—leads me to refrain from offering more than the outlines of an account of the observations made. The figures given are not meant to be more than diagrammatic careful drawings have been made which it is hoped to publish later in a botanical journal.

In previous notes[1], of the nature of progress reports, I have given some account of the internal boll disease of cotton. This affection, in its more directly economic aspects, will form the subject of a paper which is intended for early publication in this Journal. It will suffice to state now, that it is regarded as proved that the gross staining of the lint in unopened bolls, often followed by more or less rotting of the boll contents, which constitutes this disease, is due to infection which takes place as a consequence of the puncturing of the wall of the boll by plant bugs, mainly *Dysdercus* spp. and *Nezara viridula*. The infecting organism, in the great majority of cases, is one of the four fungi mentioned above. There are also infections due to one or more species of bacteria, the proportion of this type being usually rather low, but in certain circumstances, apparently connected with wet weather, becoming greatly increased.

Infections with the fungi concerned may apparently take place at any stage after the boll is well established, and the effect produced varies accordingly. In late cases only a local yellow patch is found on the lint ; in early cases the whole contents of one or more carpels may be rotted ; and there are all stages between. Bolls are most commonly examined when they are approaching maturity, and at this stage the fungus is often reduced almost entirely to spores. In other cases the hyphae (of the first three forms) are found growing vigorously in and amongst the lint and

on the seed coat, and more rarely the formation of sporangia is abundantly in evidence. The sporangia of the hyphal forms are usually readily formed on exposure of the contents of an infested boll in a moist chamber. All the forms have been held in culture on agar media for some months, and typical reproduction is obtainable in one way or another.

The species may conveniently be referred to by letter, pending further consideration as to their systematic position.

I have learnt from correspondence and exchange of cultures with Mr. S. F. Ashby, Microbiologist in the Jamaica Department of Agriculture, that he has independently discovered species A and D in cotton bolls in Jamaica, and from a report by Mr. A. W. Bartlett[2], sometime Government Botanist in British Guiana, it appears certain that he obtained species A, and probable that he saw the spores of C or D, from cotton bolls in that Colony in 1907.

In the earlier stages of the investigation, before the varying types of sporangia were seen, the spores of forms A and B, and those of C and D, were not clearly differentiated, so that observations made then as to distribution are indefinite. Examination of a large selection of bolls, made over a considerable period, will be necessary before the distribution of the forms can be adequately stated. The localities given are those which have been confirmed since the four forms were defined.

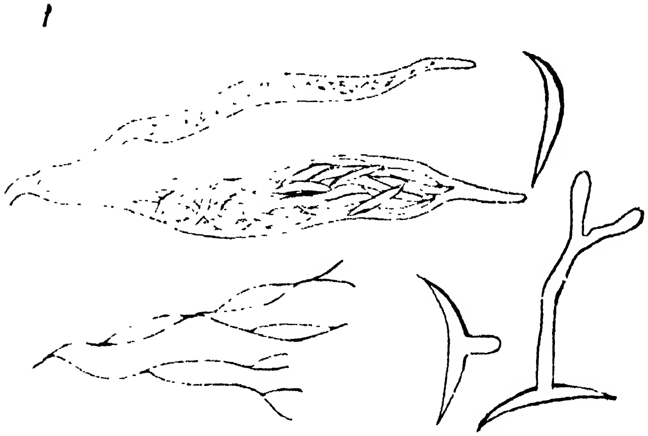

FIG. 1.

SPECIES A. (Figure 1.) This is at the present time the dominant species in the end-of-the-season infestation at the Experiment Station at Kingstown, St. Vincent. It was abundant there in January 1916; in October 1916 on the new crop it appeared to be absent from the Experiment Station, the dominating infection being bacterial, with perhaps 10 per cent. due to species D. At the same time a collection of about 100 affected bolls from a district near Georgetown showed about half of the infections due to this species, the remainder to bacteria.

The hyphae vary from fine to very coarse, are hyaline, non-septate, and branch almost entirely by regular dichotomy. In some states, seen both in cotton bolls and in cultures, small single bud-like projections are formed at fairly regular intervals along the older hyphae. The sporangia are simple expansions of the hyphae separated by a septum; they may occur intercalated singly or in chains, but are more frequently terminal. Usually a short length near the tip of the hypha remains unexpanded, but this may be absent and the sporangium have a rounded end. The spores are very numerous, and have not been seen to have any regular arrangement. They are unicellular, falcate, and are provided with a thickened rib which extends from about the middle to one end, where it projects in a fine point. They are set free by the solution of the sporangium wall.* It is at this stage they are most commonly found in maturing bolls, adhering in masses to the lint fibres. The spores germinate by sending out a single stout germ-tube, most commonly from near the middle of the convex side, but occasionally from any other situation, including the tip.

The sporangia are very variable in size, commonly about 90 × 10 *microns*; the spores measure 18 21 × 2 – 2·5.

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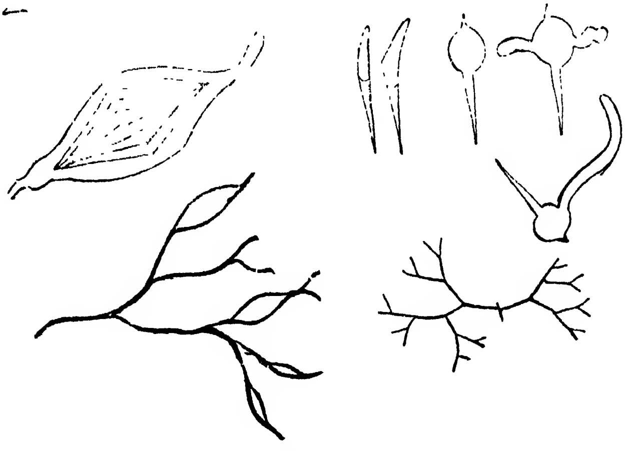

FIG. 2.

SPECIES B. (Figure 2.) This form was obtained from Tortola, Virgin Islands, in the 1915 season, and from St. Kitts in January 1917. It appears to correspond exactly with *Eremothecium cymbalariae*, Borzi, found in Italy in 1888 in the capsules of *Linaria Cymbalaria*, and in France by G. Arnaud[3] in 1906-12 in the fruits of *Cachrys laevigata*.

*In this, as in the three following species, the wall of the sporangium, which is at first as distinct as that of the hypha from which it is formed, grows rapidly more indistinct after the spores are matured, until it becomes invisible. It can sometimes be seen, in a fresh mount, reduced to extreme thinness, collapsed, and torn.

The hyphae closely resemble those of species A above, and are extremely regular in their dichotomous branching. I have seen no septae, as mentioned by Arnaud, except in connexion with the separation of the sporangium, and have observed the protoplasm streaming for long distances through the branched hyphae.

The sporangia differ only in shape from those of the last species, in conformity with the difference in spore formation. The spores are formed in two conical bundles, their broad ends interlocking.

The spores show a segregation of their contents, denoted by the deeper staining of a definite section towards the blunt end, but I have failed to see any septum. In germination this end swells into a sphere, from which one or two stout germ-tubes grow out.

The spores, from the West Indian sources indicated, measure very regularly 13·5 *microns*.

SPECIES C. (Figure 3.) In a considerable quantity of material obtained from Montserrat towards the end of the 1916-17 season nearly all the bolls were infected with this species. Other fungi were not seen, the remaining infections being bacterial. The same form has also been obtained recently from Nevis and Antigua.

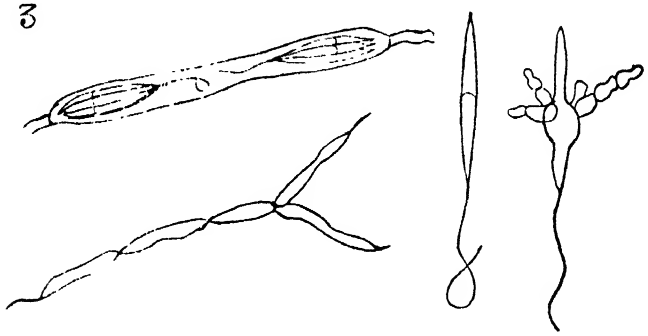

FIG. 3.

The vegetative hyphae as seen in the bolls are in general indistinguishable from those of species A and B. They exhibit the same characteristic tendency to regular bifurcation, and are almost or entirely without septae. In this condition there are often, as in species A, small bud-like projections along the course of the hyphae, but as observed so far, these have been somewhat more elongated than in that species. The hyphae as in the two previous species often occur within the lumen of the cotton fibre, and in this species sporangia are sometimes formed in that situation.

In cultures, especially when sporangium formation is active, there is a tendency for the hyphae to become remotely septate, and for a development of lateral branches which obscures the dichotomous hab t

The sporangia are formed as in A and B by the expansion of sections of hyphae, which became separated by septae. Commonly, when fruiting ensues upon a period of vegetative growth, the hyphae are almost completely converted into chains of sporangia. The expansion may be considerable, so that the sporangium has the form characteristic of species A, or it may be so slight as to be scarcely noticeable. Examples which represent the extreme of the latter type contain only one pair of spores.

The spores clearly belong to the highly peculiar type of Peglion's *Nematospora Coryli*, of Arnaud's macrospores found in association with *Eremothecium cymbalariae*, of Schneider's *Nematospora Lycopersici*, and species D of this paper. They are described below in comparison with those of species D.

They are formed in two equal opposed bundles in each sporangium, joined by a thread formed of their combined appendages. Their number varies. Bundles have been seen half opened in which at least ten could be counted, and this number does not appear to be the maximum. In other cases the number is reduced to one, as mentioned above. The numbers seen in sporangia occurring in bolls have been in general greater than in those produced in cultures, where the common number is about four. As in the previous species, the sporangium wall is gradually dissolved. In the method of spore formation, and in the form and arrangement of the spores. this species very closely resembles the next. The body of the spore measures 27 - 35 x 2, the appendage commonly 15 - 20, but sometimes much more.

Germination has been followed in nutrient liquids and on agar. The upper half (remote from the appendage) takes no visible part in the process. Just below the middle the spore wall swells out into a sphere, and the part below it also increases in width. From the walls of the spherical portion several shortly jointed rows of cells originate. These branch freely, retaining their jointed form, until a dense tuft is formed around the spore. In agar cultures these tufts resemble to the naked eye small colonies of bacteria. In conditions unfavourable to growth the cells of this mass may become dissociated and set up yeast-like budding. In favourable conditions, normal long hyphae grow out from the mass, and in time proceed to spore-formation.

SPECIES D. (Figure 4.) In distinction from the preceding forms the thallus of this species is typically yeast-like. As seen in cotton bolls, and in vigorous cultures, it is a mixture of two forms: (1) toruloid cells and cell groups, the units of which are very variable in form but generally elliptical or ovate; (2) much larger spherical cells, single or attached in small groups. These forms agree with Schneider's description of his species. He applies the term arthrospore to the second form of cell, and states that the final activity of the fungus under conditions unfavourable to growth consists in their formation. In the writer's experience these cells have been abundant from the beginning in vigorous cultures, and they are similarly present in actively developing infections of the cotton boll. The final activity in cultures, and apparently in many cases in the cotton boll as well, is the development of a thallus which is almost entirely hyphal. This development also takes place when the organism is grown in tap water. Schneider

speaks of elongated cells with 'a very close resemblance to true hyphal fungi,' but this phrase cannot be considered as covering the growth now described, in which a definite mycelium is formed of long, sparingly branched, and very sparingly septate hyphae of regular form, and with a regular method of sporangium production.

In the yeast-like type of growth the sporangia are formed by the enlargement of a single cell, dissociated at an early period from its neighbours. The organism has been kept in cultivation during most of the period from January 1916, and the development of sporangia has many times been closely followed in living colonies kept under the microscope, without any process of cell-fusion such as that described by Schneider being seen. Sporangia are not uncommonly formed by direct outgrowth from a germinating spore, as shown in Fig. 4.

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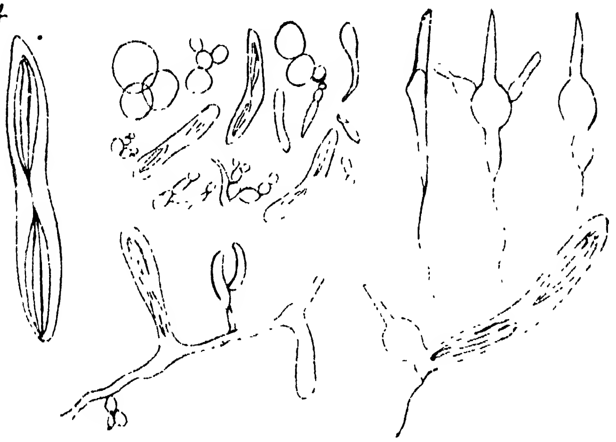

FIG. 4.

In the hyphal type the sporangia are formed as lateral club-shaped outgrowths with an enlarged base.

The spores normally occur in the sporangium in two bundles some distance apart, more or less connected by the filaments, as in the last species. In some media the sporangia are shorter, and the ends of the bundles overlap, until in extreme cases they lie side by side, as in Arnaud's figure. Occasionally a single bundle only is formed, occupying the whole of a small sporangium. These variations are also seen in species C.

The spores are spindle-shaped, produced at one end into a long whip-like appendage. Near the middle of the body, on one side, there is a slight projection (exaggerated in the sketch), and some distance above this (never opposite to it as shown by Schneider for his species), there is very commonly a line above and below which the spore shows a difference in refraction when unstained, and a marked difference in taking up stains. Most usually the half nearer the appendage stains deeply, while the upper half remains clear, but in some circumstances this action is

reversed, and occasionally no difference can be seen. My opinion so far is against the view that there is a septum at this point. An exactly similar condition occurs in the spores of species C, and something very like it in species B. Peglion's figure shows a double line in the same region.

The spores of species C differ in form from those of species D, only in the faintness of the indication of a projection on one side of the body. This feature has, however, been seen well developed in cultures on glucose agar.

The spores of D have a body length of from 30-40 *microns*, and a width of 2·3. The length of the appendage varies greatly and reaches 70 or more. These measurements agree with those of Peglion's species, while those given by Schneider (50 x 4·5) are much larger.

In the characters on which Schneider mainly bases the differentiation of his species from Peglion's (gametic origin of the 'ascus', bicellular condition of the 'ascospore', character of the 'arthrospore') the description of the present species agrees with that of Peglion.

Germination begins as described for species C, by the swelling out of a section near the middle of the spore. The nature of the outgrowth which follows is as variable as the elements which constitute the thallus. Most commonly, perhaps, several bead-like chains are produced, but their form and arrangement differ considerably, showing transitions up to the production of regular hyphal germ-tubes. In some media a sporangium is frequently produced direct.

GENERAL. Taking the hyphal form of D, the agreement in general features between the four forms described is obvious. The distinctive hyphal characters and the mode of origin of the sporangium in the first three are so close that until spore-formation begins one cannot be quite certain which species one is dealing with. Between these species and D, in which the normal form of the thallus is quite different, and the correspondence of the hyphal form is not so close, an unquestionable connexion is made by the possession in common by C and D of a very special type of spore, formed in the same peculiar way. A tendency for C under some circumstances to lose its hyphal form and become yeast-like has not yet been studied closely, but is worth mentioning in this connexion.

For the reasons given at the outset I do not carry the discussion further. Sufficient evidence has been given to show that Nematospora cannot be regarded as a Saccharomycete and that the use of the terms ascus, ascospore, and arthrospore is inadvisable, pending decision as to what position the group is to occupy. Arnaud's suggestion, that the Nematospora sporangium is a form alternative to the Eremothecium form, which I was inclined to accept when writing an earlier note, obtains no support from the prolonged culture and study of the parallel forms found in the cotton boll.

It seems probable, from the distribution of the species already found, that the group has a special habitat in fruits, and it may confidently be expected to occur in many that have not yet been

examined. It will be interesting to see how far the connexion with sucking insects, established in the case of the cotton boll, holds good with regard to the presence of members of the group in other fruits.

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POISONOUS FISHES IN THE WEST INDIES.

BY W. R. DUNLOP,

Scientific Assistant, Imperial Department of Agriculture for the West Indies.

One of the many important and interesting problems of marine biology that is deserving of systematic enquiry in the West Indies, is the subject of poisonous fishes. Not a little has been written on the subject, but the information put forward has been largely of a speculative character, and founded on local report rather than upon the evidence of direct observation and experiment. This fact only points to the need for marine research in the West Indies, where, as the present writer has shown in a previous number of this Journal, there is scope in regard to the development of the shallow-water resources of the islands (e.g. sponge and pearl oyster cultivation), and endless opportunities for organizing and introducing improved methods in regard to deep-sea fishing.

The question of poisonous fishes is one in connexion with which the marine biologist and medical investigator must needs work together It may also be necessary to seek the co-operation of the chemist. The subject has several different aspects, all of which require investigation simultaneously. The different ways in which poisoning may occur can be classified as follows :—

(1) Poisoning by ingestion, that is, by the consumption of the fish as human food. This may happen from two different causes :—

(a) The occurrence of a toxin in the body of the living fish.

(b) The production of toxins in the flesh of the fish after death due to decomposition.

(2) Poisoning by the inoculation of venom through wounds inflicted by the fish.

Most people in the West Indies are quite familiar with fish and lower forms of marine life of the second class—the Dutch Man o'War, for instance, which can inflict a most painful sting, and the Lion fish (Scorpion), which is capable of inflicting by means of its dorsal spines, wounds that are poisonous and productive of symptoms of great distress. Most people, too, have heard of cases where sickness has resulted from the consumption of stale fish, particularly in the case of the Cravallés, which tend to decompose after death with great rapidity. The first class of fish, however, the flesh of which is poisonous during life, is not so definitely recognized; indeed where cases of poisoning have occurred through the consumption of fish, they have generally been attributed to the production of toxins in the fish after its death, or its having fed on poisonous material previous to being caught. There is evidence to show that this is not always the real cause—that some fish are actually poisonous while alive. An authentic case of this is recorded from St. Kitts, where not long ago three cases of severe illness and two deaths in the same household in one night were caused by the consumption of a Barracouta caught the same day. This unfortunate event led the Government of the Leeward Islands to make enquiries at the British Museum (Natural History), and that institution subsequently issued a short report on the subject of the present paper, and it was circularized by the Colonial Office and published in the Colonial *Official Gazettes*. Three other reliable instances of poisoning—without fatal results—from eating the flesh of Barracouta have been brought to the notice of the present writer, by the Revd. E. N. Watson, F.L.S., of Barbados. So that there is no question as to the possibility of certain species of fish being able to produce, while in a fresh state, poisoning of a serious character by ingestion. Admittedly the cases are not of frequent and constant occurrence; but it is just this fact which makes investigation desirable, in order to protect those who, by force of circumstances perhaps, rather than by choice, run a considerable risk by eating species that should be avoided.

The present writer has made general enquiries on the subject, and perused such literature as is available on poisonous fishes in the West Indies; and the following observations recorded by different authorities seem to be worth reproduction. It should be stated that there appears to be considerable confusion in regard to the use of the scientific names employed, so that one cannot always tell exactly to what species reference is being made. However, identities can be made out sufficiently closely to serve the general purpose of the present paper.

It has been found convenient to group the observations under family headings, and to arrange these families in ascending natural order, according to the classification of Professor Bridge and G. A. Boulenger, F.R.S. (The *Cambridge Natural History*, Vol. VII, 1910.)

SPHYRAENIDAE (BARRACOUTAS).

The Barracouta 'proves sometimes poisonous when caught near St. Eustatius or among the Virgin Islands: the real cause of its poisonous qualities at certain times is still unknown' (Schomburgk). Evermann and Marsh say: 'Many of them (species of Sphyraena) are valued as food.'

Pellegrin refers to eight different authors all of whom state that the consumption of the flesh of the large Barracouta is often dangerous. One of these (Poey) says that the large Barracouta sometimes contracts an infectious disease the symptoms of which can be seen in the flesh. This disease is believed to give rise to toxins.

CLUPIDAE (HERRINGS AND SPRATS).

Pellegrin refers to *Clupea humeralis* as the common species in the West Indian waters. He states: 'Although in certain localities of the Antilles this fish may be appreciated and constantly consumed, it would be easy at times to detect poison.'

According to Schomburgk: 'A species called the yellow-tailed sprat proves unfortunately poisonous at certain periods of the year in some of the islands, chiefly among the Leeward and Virgin Islands.'

MURAENIDAE (MORAYS OR TROPICAL EELS).

Referring to *Muraena moringa*, Pellegrin says: 'This species which lives in the Antilles, is eaten frequently in Havana. Although Hill regards it with suspicion it may perhaps be eaten without any fear. That which there is to fear is the bite of this fish.'

This is supported by Evermann and Marsh, who state: 'They inhabit tropical and sub-tropical waters, being especially prevalent in crevaces around coral reefs. Many of the species reach a large size and are all voracious and pugnacious.'

More definite information is given by Calmette, who refers to the poison apparatus in *M. moringa*, consisting of a pouch situated above the membrane of the palate, which may contain ½ c c. of venom, and three or four conical curved teeth with the convex surface in front, as in the fangs of snakes.

SCARIDAE (THE PARROT FISHES).

Scarus vetula, 'mud fish' or 'old wife' is one of the most gaudy of the Parrot fishes and is common in West Indian waters A case of illness from eating Parrot fish has recently been reported to the present writer from St. Vincent Pellegrin says: 'Moreen de Jonnès includes it in his list of poisonous fishes.'

CARANGIDAE (JACKS) AND SCROMBRIDAE (CREVALLES).

Caranx latus, the horse-eye Jack, is very abundant in the West Indies. According to Schomburgk: 'The Jacks are in

some seasons of the year, especially Christ Church parish (Barbados) or thereabouts, very poisonous, and that at such times there are in their gills two small red lumps. When they are suspected of being poisonous an experiment is tried on a duck, by giving her one of them to swallow, and if at that season it is poisonous, the duck dies in about two hours.'

Evermann and Marsh, referring to *C. latus*, state: 'The poisonous character sometimes attributed to its flesh evidently does not attach to it in Porto Rico, where it may be found for sale in the markets.'

Pellegrin states: 'It is a very dangerous species having caused mortality many times, and one which ought particularly to be held in suspicion.'

Scorpoenidae (Scorpion Fish).

The two most common species in the West Indies are *S. grandicornis* (the Lion fish), and *S. plumieri.*

The Lion fish is dangerous on account of the poisonous wounds inflicted by its dorsal spines.

Schomburgk says: 'Inflicts a wound with its spines that causes the most violent pain.' In regard to *S. brasiliensis,* he states: 'The flesh, which is coarse, has proved occasionally poisonous.'

Pellegrin, Evermann and Marsh all refer to the dangerous character of these fishes.

Batrachidae.

Calmette states that the dorsal and anterior spines, as well as the spine on the top of the operculum of *Batrachus grunniens* (Grunting Batrachus of the West Indies) have poison sacs at the base of each.

Balistidae (Trigger Fishes).

Pellegrin, referring to *Balistes vetula* says: 'This species is met with in the tropical parts of the Atlantic, principally in the Antilles. In Cuba it goes by name of "Cochino"—although Poey has no knowledge of any accident by poisoning, the fish is suspected by Moreau de Jonnés, Moret and Janière, who report a case in Guadeloupe where twenty persons were poisoned by eating it.'

Evermann and Marsh say: 'Shore fishes of the tropical seas, of rather large size, carnivorous or partly herbivorous—they are rarely used as food, many of them being reputed as poisonous. According to Dr. Day: "Eating the flesh of these fishes occasions in places symptoms of the most violent poisoning." Dr. Mennier at Mauritius, considers that the poisonous flesh acts primarily on the nervous tissue of the stomach, accasioning violent spasms of that organ and shortly afterwards of all the muscles of the body. The frame becomes racked with spasms, the tongue thickened, the eye fixed, the breathing laborious, and the patient expires in a paroxism of extreme suffering.'

Ostraciontidae.

Ostracion triqueter (Drunken or Plate fish). 'There is a gelatinous matter contained near where the tail is joined to the osseous plates, which is called the jelly, and a similar matter is found near the head. When only part of the jelly has been swallowed its effects are uncommonly vertigo and sickness of the stomach with pain in all the limbs, but chiefly in the lower extremities. The feeling of vertigo is said to be similar to intoxication, hence it has received the name of drunken fish among the common people. It should never be neglected to remove the jelly, as there is an instance known to me where such a neglect proved fatal to two persons who ate of it.' (Schomburgk.)

Pellegrin also includes this and other species of Ostracion amongst the poisonous fishes.

Diodontidae and Tetrodontidae (Globe and Porcupine Fishes).

'Rarely used as food, being generally regarded as poisonous (Evermann and Marsh).

Pellegrin says: 'They share the toxic properties of all the Gymnodontes with the Diodons as with the Tetrodons; it is at the spawning period that they become most dangerous, and they appear to be equally often as dangerous.' Schomburgk, in referring to *Diodon obicularis* ('Pricky Orb' of Barbados) says: 'The flesh proves sometimes poisonous.'

Calmette states: 'Several species of Tetrodon are armed with spines which produce very painful wounds. Their flesh is toxic, but it has not been proved that poison glands exist at the base of the spines.'

Note:—The poisonous characters of certain species of genera belonging to the Sphyraenidae, Scaridae, Scorpoenidae, Batrachidae, Balistidae, Tetrontidae and Diontidae, are referred to by Professor Bridge and G. A. Boulenger, F.R.S.

Other Dangerous Forms of Marine Life.

The foregoing notes refer to the true fishes. There are lower forms of marine life that occur commonly in West Indian waters that are dangerous. The Dutch Man-o'-War and the Jelly fish inflict painful stings, and the painful character of wounds inflicted by the spines of the 'sea-egg' is probably known to most people who have indulged in sea bathing, particularly in Barbados. A word of warning might be added here in regard to crabs and lobsters; not so much from the point of view that they inflict painful wounds, but rather in reference to the fact, that at times they appear to be unwholesome as food. This condition seems to be determined by the nature of the material they have eaten before being caught. It is of interest to note that the Rev. John Smith, in his History of Nevis, published many years ago, states that whereas lobsters caught on the Leeward side of the island were found to be good eating, those captured on the Windward side were found to be poisonous.

Finally a note concerning the flying fish. In Barbados the notion is prevalent that feathered flying fish, i.e. parasitized by the Copepod parasite, is unwholesome. There does not appear to be any direct evidence in support of this idea.

NATURE OF THE POISONING.

It has already been stated that poisonous fishes may be divided into two main classes: (1) those which give rise to poisoning by ingestion; (2) those which cause poisoning by inoculation, i.e. by the infliction of venomous wounds. It will be convenient to refer to the poisons associated with the first class as toxins; and to refer to those of the second class as venoms. More appears to be known about venoms than toxins, probably on account of the considerable amount of research that has been carried out in connexion with poisonous snakes. The venom of the Weever—a European poisonous fish, appears to have received the most attention, but according to Calmette, the venoms of all the fishes referred to as venomous in the preceding pages present a fairly close resemblance as regards physiological action, to the venom of the Weever, and show scarcely any variation except in the intensity of their effects.

The following is Calmette's account of the venom of the Weever, and its effects:—

'The venom of the Weever has formed the subject of interesting studies by Gunther, Gressin, Bottard, Phisalix, and more recently by Kobert and A. Briot.

'In order to procure sufficient quantities of it for experimental purposes, Briot cuts off the venomous spines and the surrounding tissue with a pair of scissors: he then pounds the whole in a mortar, and mixes the pulp with pure glycerine. After filtration through paper, a toxic solution is obtained, which does not deteriorate by keeping, and is neutral to litmus.

'A few drops of this liquid are sufficient to kill guinea pigs, which, immediately after receiving an injection in the thigh, exhibit paralysis of the leg with tetanic convulsions; twenty-four hours later an eschar is formed, and death supervenes on the second or third day.

'Two or three drops, introduced into the marginal vein of the ear of the rabbit, cause death from asphyxia in from four to ten minutes. The heart continues to beat for a fairly long time after respiration has entirely ceased; the blood is not coagulated.

'The toxicity of this venom is completely destroyed by heating it 100° C., by chloride of lime, and by chloride of gold. Antivenomous serum prepared from horses vaccinated against cobra-venom has absolutely no effect upon it *in vitro*. There is, therefore, no affinity between this venom and that of snakes.

'Weever-venom dissolves the red corpuscles of the horse in the presence of normal heated horse-serum, but does not dissolve them in the presence of fresh serum. The non-heated serum therefore, as I have shown with reference to the action of cobra-venom on the blood, contains a natural antihaemolysin.

'Briot succeeded in vaccinating rabbits by accustoming them to the venom, and in obtaining from them a serum capable of neutralizing the latter *in vitro*, and of immunising fresh rabbits against doses several times lethal, even when injected intravenously.

'According to Gressin, the following phenomena are pro-produced in man as the result of Weever-stings :—

"At first there is felt an excruciating, shooting, paralysing pain, which, in the case of nervous persons, may cause attacks of leipothymia, ending in syncope. A kind of painful formication next prevades the injured limb, which becomes swollen and inflamed, and may even, if treatment be neglected, form the starting point of a gangrenous phlegmon.

"This condition is frequently accompanied by certain general phenomena—such as fever, delirium, and bilious vomiting, the duration of which is variable, since they may only last for two or three hours, or may continue for several days. Fishermen rightly consider this variability to depend upon the amount of venom that has penetrated into the wound, and especially upon the season at which the accident takes place. The most serious results are recorded during the spawning season, and fishermen regard the Lesser Weever as being the most poisonous." '

The present writer has been informed by Dr. R. M. Johnson, Government Bacteriologist, Barbados, that three cases of poisoning by venomous fishes have come under his notice, and the symptoms were similar to those described above. Dr. Johnson has found that by far the most effective treatment is to inject morphia hypodermically. This generally causes the symptoms to disappear in less than ten minutes.

The literature available does not furnish any such definite information regarding the toxins associated with the flesh of fish. Pellegrin discusses the matter in a general way, pointing out that the toxins may originate in several ways. They may be secreted in the animal body for protective purposes in connexion with egg-production ; they may arise as the result of some pathological condition, which is believed to be the case with poisonous Barracouta ; they may exist as the result of the fish having fed upon poisonous algae ; to the contamination of shallow sea-water with sewerage, or to decomposition changes in the flesh after the death of the fish. All these possibilities make the subject a very difficult one to investigate. And one has to take into account that some fish are much more digestible than others, and that the digestive powers and susceptibility to poisoning vary amongst different people.

The toxins that occur in flesh are generally regarded as coming under two catagories : in the living flesh we have a group of alkaloids known under the general terms of leucomaines ; while in the dead flesh, the poisonous alkaloids that may be formed are referred to as ptomaines. As already stated, information as to the properties of the leucomaines and ptomaines that sometimes exist in the flesh of fish is not available : though they may not differ essentially from the venoms, there is no direct evidence to prove it.

Pellegrin describes some of the symptoms produced in human beings by the consumption of poisonous fish. Thus, speaking of the Tetrodons, he says : 'The action is a paralysis of the central nerves which reacts more or less on the general and special senses and on the motor nerves, and death is caused by paralysis of the heart and asphyxiation.' This refers, of course, to very acute cases.

The effects of poisoning may be better described, perhaps, as taking two forms :—

(1) The algid or cold form (cholic and paralysis).
(2) The gastro-enteric form.

In the first form the patient quickly falls into a state of prostration, and coma followed by death is the invariable termination. It lasts from twenty minutes to several hours.

In the second, there is violent irritation of the stomach and intestines, resulting in violent vomiting and diarrhœa. Termination is sometimes fatal, but generally the trouble is local, confined to the digestive track, and the patient eventually recovers.

Details as to the symptoms observed in these two forms will be found in Pellegrin's Thesis (see list of references).

As regards treatment, no specific antidote appears to be known against fish poisoning. The usual treatment is to administer an emetic. Electric treatment, if available, is stated to be beneficial. Artificial respiration is sometimes applied ; it is important to keep the patient in a recumbent position. The administration of alcohol is generally found useful to revive the patient, if not to assist in the neutralization of the poison.

During convalescence, it is obviously important to prescribe an easily assimilable diet.

CONCLUSION.

In the foregoing pages an attempt has been made to bring together such information as is available in regard to fish poisoning in the West Indies. There are undoubtedly several species of fish common in these waters of which the flesh, even though freshly cooked, is highly dangerous to consume. There are other fish which are dangerous on account of their venomous characters. Cases of fish poisoning by ingestion are not, as far as we know, of common occurrence, possibly on account of the fact that there is generally a sufficient supply of fish which is known to be perfectly wholesome and beyond suspicion. Cases have occurred from time to time, however, and care should be taken to avoid as far as possible those species referred to in the present paper. In general, any but freshly caught fish should be avoided, and the greatest care taken in preparing it for consumption, to remove all traces of the internal organs with which poison may be associated under certain conditions, particularly at the spawning period. All due caution should be exercised by fishermen and by bathers in regard to the avoidance of venomous forms in the sea.

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MANURIAL EXPERIMENTS WITH SEA ISLAND COTTON IN ST. VINCENT, WITH SOME NOTES ON FACTORS AFFECTING THE YIELD.

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INTRODUCTION.

The investigations which are to be described have proceeded along the following lines:—

(1) A study has been made of the data available from the manurial experiments in St. Vincent during the past five years* (1912-16 inclusive).

(2) The number of flowers opening daily in every plot of the Manurial Series from September 8 to February 14 has been recorded.

(3) The number of bolls opening daily in every plot of the Manurial Series has been recorded for a period of fifty-three days. After that pickings were made at intervals of five days.

(4) A daily examination has been made of some thirty plants, and as far as possible an accurate record kept of the fate of every bud, flower, and boll produced. This intensive examination has made it possible to trace the effect of environmental conditions on the plant in a way that is very precise.

(5) Use has been made of the meteorological observations which are a part of the daily routine work of the Experiment Station.

* For the results of 1912, 1913 and 1914, the Author is indebted to Mr. W. N. Sands, Agricultural Superintendent.

The observations which have been made use of comprise:

(a) Relative Humidity (wet and dry bulbs).
(b) Rainfall.

Records of relative humidity are taken at 9 a.m. and 3 p.m. each day, while the rainfall is measured each morning at 9 a.m.

Had the requisite instruments been available a more detailed correlation might have been attempted between weather and soil conditions and the reaction thereto of the cotton plant.

Any correlation suggested in the following pages will be found to be of a very broad and general nature.

THE MANURIAL PLOTS.

A rectangular strip of ground is divided into twenty-four plots—three series of eight. Each plot is $\frac{1}{40}$-acre in area. To each of the eight plots in a series is applied a different combination of manure, and this is repeated in the second and third series so that there are three plots for each combination.

The experiments were started in 1912-13, and each season the yield of seed-cotton for each plot has been determined and the results set forth, calculated to the acre.

A plan of a single series is given in Fig. 1; the twenty-four plots form a continuous strip.

Path.									
Grassed cart road.									
	1	2	3	4	5	6	7	8	
Path.	No manure.	Nitrogen.	Phosphate.	Potash.	Phosphate and potash.	Nitrogen phosphate and potash.	Cotton seed meal.	Cotton seed meal phosphate and potash.	Path.

FIG 1.

Plan of Series 1 in Manurial Experiments.

SOWING DISTANCE. The plants are sown 2 feet apart on ridges which are 5 feet apart. One plant only is left in each hole. There are thus 4,356 plants to the acre.

SOWING DATE. The plots are usually sown at the beginning of July but the time has varied in different years.

PREPARATION OF PLOTS. The plots are prepared several weeks before the seed is sown by forking and pulverising the soil, and by burying weeds under the ridges. If planted too soon after burying the weeds the seeds do not germinate well.

APPLICATION OF MANURES. Manures are applied by hand a few days before planting, and a still morning is chosen for the operation. The sulphate of ammonia is applied when the plants are showing the second leaf. In order that the manures may be spread evenly they are mixed with a considerable quantity of fine dry earth.

THE SOIL. The soil is a light sandy loam, by no means uniform in depth or in quality. The site of the plots, however, was the best that could be found on the Experiment Station.

On one side a grassed cart road bounds the plots and this has a well marked effect. The row nearest the road is in general more vigorous than the inside rows. The reason for this is not known. Perhaps it is due to the fact that the plants are able to make use of nitrogen fixed by bacteria associated with grass-land, or to the different state of consolidation of the soil. The 'fallow effect' of a path is alluded to by A. D. Hall. (4)

AFTER-TREATMENT OF THE CROP. This consists in :—

(1) Frequently stirring the surface soil until the plants are about three months old.

(2) Keeping the ground free from weeds until the plants are about four months old. After that few weeds can grow beneath the heavy shade.

(3) Gathering the seed-cotton as it becomes available and weighing it carefully when quite dry.

It must be noted that in St. Vincent there is no such thing as the Egyptian first, second and third pickings. As soon as the bolls open, the seed-cotton must be picked. It cannot be left on the plants for more than a few days. Heavy rains lasting two days will cause the seeds to germinate in the locks and the lint to spoil. Pickings are made at intervals of two or three days throughout the maturing season.

(4) Pulling up, carting away, and burning the plants after the crop has been reaped. The plants are not burned anywhere on the manurial plots so that there is no danger of upsetting the fertility of any particular plot.

A large amount of plant food must be removed each year with the plants, and it is certain that the cotton lands of St. Vincent are being rendered poorer year by year by the same practice.

Burning is alleged to be necessary for the control of leaf-blister mite (*Eriophyes gossypii*, Banks), black scale (*Saissetia nigra*, Nietn.) and possibly certain of the fungoid diseases. In St. Kitts, the general practice is to bury rather than to burn, with no deleterious effect, and it is perhaps time for the relative merits of the two methods to receive the serious attention of St. Vincent planters.

General Considerations in Conducting Manurial Experiments with Cotton.

It should not be lost sight of that there is this great difference between cotton and a crop like wheat or maize. In the

case of these two latter crops there is a certain definite period at which the crop is known to be ready for reaping. If the crop be left after this time it will spoil. In the West Indies, with its equable temperatures, Sea Island cotton could be grown for more than one season were it not for the pests leaf-blister mite and black scale. Now, under West Indian conditions it is scarcely possible to state when a cotton field has finished bearing, as there are always large numbers of buds, flowers, and bolls on the plants when the latter are pulled up. According to the kind of season experienced, cotton fields never have the same vegetative period in two successive years, and a source of error is thus introduced into manurial experiments.

The dates of sowing and pulling up, with the length of the vegetative period in the seasons 1912-16, are given in Table I.

TABLE I.

SHOWING DATES OF SOWING AND PULLING UP WITH THE LENGTH OF THE PERIOD OF GROWTH.

Year.	Date of sowing.	Date of pulling up.	Period of growth.
1912-13	June 28, '12	Jan. 27, '13	213 days
1913-14	June 21, '13	Feb. 25, '14	249 „
1914-15	June 19, '14	Jan. 21, '15	216 „
1915-16	July 17, '15	Jan. 12, '16	179 „
1916-17	July 7, '16	Feb., 14 '17	222 „

In conducting manurial experiments with cotton there is a dual object in view. The planter requires to know what manure will give him the best monetary return from his land, but it is also very important for the scientific worker to know what effect different manures have on the growth of the plant, i.e. a manurial experiment should also be an experiment in plant physiology. The scientific worker desires to know the particular part played by particular elements in the nutrition of the plant, and since the results of one year's experiments may be obscured or vitiated by environmental factors, it is best to grow the crop year after year on the same land, and no other crop. The function of the different elements will thus gradually come to light.

The point brought out by W. L. Balls(1) is worth considering. He makes the following statement: 'The mere figures for yield mean very little, since the same final result may be reached in an infinite number of different ways. If we can not only ascertain exactly how the yield was produced, day by day, but also trace back the fruits to their origin as flowers and the flowers to their origin as buds on the scaffolding of flowering branches, we have resolved the agricultural problem into components which the botanist can deal with.'

Hitherto, with the possible exception of Balls's own work in Egypt, investigations on the manuring of cotton have been confined largely to only one aspect of the problem, the yield of seed-cotton. The effect of various factors on the productivity of the cotton plant can be stated in terms of the amount of seed-cotton produced by the plant, only if it be assumed that the factors which prevent buds becoming flowers or flowers in their turn becoming ripe bolls react equally on all plants.

Consider these two cases :—

(a) An identically treated plot producing the same yield in different years.

(b) Two identically treated adjacent plots in the same year producing the same yield as each other.

We can say at once that the yields in the first case must have been built up by the interaction of two distinct sets of factors, since weather conditions are never alike in any two years. It has been within the province of these investigations to consider the second case, and from them it has been concluded that in this case, the way in which the crop is built up is the same in both plots. The data upon which this conclusion is based will be given later.

The practical importance of it is great since it may be said that in a single season, provided the area under experiment is not too large, a fairly accurate comparison of the effects of environment, manures, etc., on the yield of seed-cotton, based on the yield of seed-cotton only, may be made.

At the same time an intensive study of the way in which the yield is built up from day to day is even more important, since it is only by this means that any idea can be formed of the size of the potential crop, uninfluenced by unfavourable conditions.

During the season 1916-17, therefore, it was resolved to follow the fate of the flowers and bolls on a number of plants, and also to record the rates of flowering and bolling of the manurial plots. Unfortunately it was not possible to begin the more intensive set of records until the plants had been in flower for about a month. Sufficient data have been accumulated however, upon which to base certain quite definite conclusions.

THE RESULTS OF THE MANURIAL EXPERIMENTS FROM 1912–16.

In Table II will be found the results of the Manurial Experiments from 1912 to 1916, stated in terms of the amount of seed-cotton produced by each plot, calculated to the acre.

Table III contains the results of the season 1916-17 and presents the number of flowers and bolls produced by each plot, the percentage of flowers which produced bolls, and also the increased yield of the manured plots compared with the unmanured, assigning to the unmanured plots an arbitrary value of 100.

Table IV shows the variation of the plots from year to year in relative order of merit.

All these results may be conveniently discussed together.

In the first place it is seen that the percentage of flowers maturing into bolls does not vary greatly in the different plots.

It would be unsafe to assume that the variations which occur are the result of any difference in manurial treatment. The first important conclusion may be stated as follows :—

Differences in manurial treatment do not cause any notable differences in the percentage of flowers producing ripe bolls.

In regard to the relation of the different manures to yield, a comparison of the results in Table II will show that great variations in yield are manifested from year to year. Thus the 1914-15 results are in every case better than the 1913-14, and the superiority in yield of the former season is largely due to more favourable weather conditions. On the whole, however, there are certain general conclusions which it is possible to make. In 1916-17, the last year under review, it will be observed that :—

(1) All the manured plots show an increased yield over the unmanured, the increase in the case of No. 8 amounting to as much as 116 per cent.

(2) The element most necessary is potassium, an application of potash producing an increase of 76 per cent. In connexion with this point it will be instructive to quote from the well-known Bulletin on Sea Island cotton issued by the United States Department of Agriculture :—

'A liberal supply of potash is very important for Sea Island cotton, and farmers outside of the Sea Islands use too little of it. Potassium influences the formation of starches and sugars in the plant and appears to be indispensable for protein formation. A lack of it in the case of Sea Island cotton may lead to the appearance of "rust"—a disease resulting from disordered nutrition.'

It is noteworthy that in the manurial plots the lack of potash produced this physiological affection, which manifests itself by the production of reddish-coloured leaves which tend to drop prematurely.

The 'rust'—which must not be confused with the disease *Uredo gossypii*, was noticeable chiefly in the no-manure, nitrogen, and phosphate plots. A slight amount appeared in the cotton-seed meal plots, tending to show that these plots were not receiving an adequate supply of potash. There is no evidence that the 'rust' leads to any diminution in the number of bolls which open, when once formed.

(3) For some unknown reason an application of phosphate and potash is less beneficial than potash alone. The difference in yield between plots 4 and 5 is apparently quite significant, but the experiments require to be conducted further before discussion can have much value.

(4) Artificials and cotton-seed meal are better than cotton-seed meal alone or artificials alone.

(5) It appears that an application of cotton-seed meal at the rate of 600 lb. per acre is insufficient to meet the full requirements of the plants when grown on the same land for a number of years. It is to be regretted that an experiment was not included to compare the value of a heavy dressing of pen manure with the other manures, but the results presented are a very strong argument for the keeping up of the fertility of the soil by means of as heavy applications of manure as possible, and by a rational system of crop rotation.

Table IV enables conclusions to be drawn similar to those already arrived at. It will be seen that the general tendencies are as follows :—

(1) The no-manure plots get lower.

(2) The nitrogen plots get lower.

(3) The phosphate plots get lower.

(4) The potash plots get higher.

(5) The phosphate-potash plots are erratic (two become higher, one lower).

(6) The complete artificial plots get higher.

(7) The cotton-seed meal plots are erratic, but, on the whole, get higher.

(8) The artificials cotton-seed meal plots all get higher.

TABLE II.

THE YIELD OF THE MANURIAL PLOTS 1912-16.

Results stated in lb. per acre of seed-cotton.

Description of manures.	Plot.	1912-13. Yield.	1912-13. Average.	1913-14.	1913-14. Average.	1914-15.	1914-15. Average.	1915-16.	1915-16. Average.	1916-17.	1916-17. Average.
	1a	943		789		529		392		220	
No manure.	1b	476	663	578	573	735	623	606	526	242	237
	1c	569		352		606		724		248	
Nitrogen as	2a	980		719		543		452		128	
sulphate of ammonia,	2b	628	862	471	529	750	678	756	720	301	258
30 lb. per acre.	2c	978		396		740		953		344	
Phosphorus as	3a	901		545		676		389		115	
basic slag,	3b	939	898	438	458	750	720	708	625	358	274
40 lb. per acre.	3c	855		391		733		777		349	
Potassium as	4a	733		852		878		581		345	
sulphate of potash,	4b	779	753	547	605	761	777	720	728	375	404
30 lb. per acre.	4c	746		417		691		883		492	
Phosphorus (40)	5a	759		647		689		776		307	
Potassium (30)	5b	938	842	555	501	695	699	595	764	369	244
	5c	830		302		713		922		356	
Nitrogen (30)	6a	811		594		599		830		316	
Phosphorus (40	6b	719	629	479	485	705	667	859	831	540	431
Potassium (30)	6c	356		382		698		803		438	
Cotton-seed	7a	784		759		724		578		228	
meal,	7b	873	721	383	447	699	688	672	620	361	332
600 lb. per acre.	7c	505		199		640		609		407	
Phosphorus (40)	8a	831		712		938		665		485	
Potassium (30) Cotton-seed meal (600)	8b	876	753	539	533	756	785	737	661	418	511
	[illegible]	[illegible]		[illegible]		[illegible]		[illegible]		[illegible]	

TABLE III.

RESULTS OF 1916-17.

Manure.	Plot.	Number of flowers.	Number of bolls.	Per cent. bolls to flowers.	Average.	Yield in lb. per acre.	Average.	Difference on No manure N.M. = 100
No manure.	1a	6,300	1,003	15·9		220		
	1b	6,252	1,103	17·6	17·2	242	237	
	1c	6,229	1,129	18·1		248		
Nitrogen.	2a	3,845	582	15·1		128		
	2b	9,239	1,369	14·8	15·4	301	258	+ 9%
	2c	9,557	1,566	16·4		344		
Phosphorus.	3a	4,568	525	11·5		115		
	3b	8,332	1,630	19·6	15·8	358	274	+ 16%
	3c	9,817	1,588	16·2		349		
Potassium.	4a	9,579	1,571	16·4		345		
	4b	9,659	1,707	17·7	17·0	375	404	+ 76%
	4c	13,205	2,240	17·0		492		
Phosphorus and potassium.	5a	7,877	1,395	17·2		307		
	5b	9,623	1,677	17·4	16·5	369	344	+ 45%
	5c	10,954	1,619	14·8		356		
Nitrogen, phosphorus and potassium.	6a	9,221	1,436	15·6		316		
	6b	11,905	2,459	20·7	17·6	540	431	+ 82%
	6c	11,971	1,993	16·6		438		
Cotton-seed meal.	7a	7,871	1,039	13·2		228		
	7b	8,711	1,643	18·9	15·9	361	332	+ 40%
	7c	11,869	1,851	15·7		407		
Phosphorus, potassium and cotton-seed meal.	8a	11,471	2,207	19·2		485		
	8b	9,940	1,900	19·1	19·5	418	511	+116%
	8c	14,035	2,816	20·1		630		

Table IV.

<table>
<tr><th rowspan="2">Plot</th><th colspan="11">SHOWING VARIATION IN RELATIVE ORDER OF MERIT.</th></tr>
<tr><th>Manure.</th><th colspan="2">1912-13.</th><th colspan="2">1913-14.</th><th colspan="2">1914-15.</th><th colspan="2">1915-16.</th><th colspan="2">1916-17.</th></tr>
<tr><th></th><th></th><th></th><th>Av.</th><th></th><th>Av.</th><th></th><th>Av.</th><th></th><th>Av.</th><th></th><th>Av.</th></tr>
<tr><td>1 a
1 b
1 c</td><td>No manure.</td><td>2
8
5</td><td>7</td><td>2
4
5</td><td>2</td><td>8
5
8</td><td>8</td><td>7
8
6</td><td>8</td><td>6
8
8</td><td>8</td></tr>
<tr><td>2 a
2 b
2 c</td><td>Nitrogen.</td><td>1
7
1</td><td>2</td><td>4
6
2</td><td>4</td><td>7
4
1</td><td>6</td><td>6
2
1</td><td>4</td><td>7
7
7</td><td>7</td></tr>
<tr><td>3 a
3 b
3 c</td><td>Phosphorus.</td><td>3
1
2</td><td>1</td><td>8
7
3</td><td>7</td><td>5
3
2</td><td>3</td><td>8
5
5</td><td>6</td><td>8
6
6</td><td>6</td></tr>
<tr><td>4 a
4 b
4 c</td><td>Potassium.</td><td>8
5
4</td><td>5</td><td>1
3
1</td><td>1</td><td>2
1
5</td><td>2</td><td>4
4
3</td><td>3</td><td>2
3
2</td><td>3</td></tr>
<tr><td>5 a
5 b
5 c</td><td>Phosphorus and potassium.</td><td>7
2
3</td><td>3</td><td>6
2
7</td><td>5</td><td>4
8
3</td><td>4</td><td>2
2
2</td><td>2</td><td>4
4
5</td><td>4</td></tr>
<tr><td>6 a
6 b
6 c</td><td>Nitrogen, phosphorus and potassium.</td><td>5
6
8</td><td>8</td><td>7
5
4</td><td>6</td><td>6
6
4</td><td>7</td><td>1
1
4</td><td>1</td><td>3
1
3</td><td>2</td></tr>
<tr><td>7 a
7 b
7 c</td><td>Cotton-seed meal.</td><td>6
4
7</td><td>6</td><td>3
8
8</td><td>8</td><td>3
7
7</td><td>5</td><td>5
6
7</td><td>7</td><td>5
5
4</td><td>5</td></tr>
<tr><td>8 a
8 b
8 c</td><td>Cotton-seed meal, phosphorus and potassium.</td><td>4
3
6</td><td>4</td><td>5
4
6</td><td>4</td><td>1
2
6</td><td>1</td><td>3
3
8</td><td>5</td><td>1
2
1</td><td>1</td></tr>
</table>

Note: The columns headed 'average' refer to the order of merit in respect of the yield of each set of three plots as given in Table 2.

Probable Error of the Results.

The following passage is taken from A. D. Hall [4] :—

'Table CIV represents the results of 5 years' experiments with different crops on five similarly treated plots in Little Hoos field, reduced each year to a common standard by taking the mean of the five as 100.

'Table CIV.

Plot.	1904.	1905.	1906.	1907.	1908.	Mean of 5 years.
A	98·1	88·8	95·8	86·3	92·8	92·3±1·4
B	95·8	92·1	90·6	95·1	94·9	93·7±0·7
C	101·0	98·9	99·2	102·4	100·2	100·3±0·6
D	101·7	174·1	105·0	109·1	114·9	109·0±1·7
E	103·4	105·8	109·2	107·0	97·3	104·5±1·4'

It will be seen that the variations from the mean of the single plots in any given year are considerable, the mean error being ±7·5 on the assumption that all the plots should be exactly alike. A similar plan has been followed for the eight St. Vincent no-manure plots. Table V represents the results of five years' experiments on the three no-manure plots, reduced to a common standard by taking the mean of the three as 100.

Table V.

Plot.	1912.	1913.	1914.	1915.	1916.	Mean of 5 years.
IA	142·2	137·7	84·9	74·1	92·9	106·4±9·5
IB	71·7	100·9	118·0	87·5	102·2	96·1±5·2
IC	85·8	61·4	99·5	136·8	104·8	97·7±8·3

Allowing for the difference in the number of plots in Hall's series, it will be seen that the probable error of the St. Vincent experiments is much greater and the variations from the mean more considerable. The percentage of loss varies so much from year to year that it is of little use comparing the yield of a plot in one year with that of another. In the St. Vincent experiments the mean error is 24·6 on the assumption that all the plots should be exactly alike.

The Flowering and Bolling Curves.

It should be noted that in the West Indies we are not concerned with the 'time of arrival' of the crop, as planters are in Egypt. Variations in temperature are so slight that the plants grow at similar rates whatever the planting season, and always flower within a few days of two months. This applies of course to normal plants with an adequate water-supply. Plants stunted through drought or poor soil naturally flower rather later. The number of flowers opening in each plot of the manurial series has been recorded each day from September 8 to February 14. The counting was done by two trained assistants and the numbers checked frequently by re-counting. The total number of flowers for each plot is probably quite accurate. I have followed the method of Balls in Egypt, presenting the data in graphical form. The flowers and bolls are reduced to five-day means as 'per plant per day'. During fifty-three successive days, the mature bolls were collected. It was, however, found impossible to get through the work, so pickings were made thereafter at five day intervals. In estimating the number of bolls from each plot a separation had to be made of diseased and healthy bolls. In practice, if a boll was more than half diseased it was neglected; if less than half, it was included with the healthy bolls. It will thus be seen that work of this kind demands more attention in the West Indies than in Egypt.

The flowering and bolling curves on Plate 1 enable the whole position to be summed up briefly as follows :—

(1) The flowering curve rises rapidly to a high point in the 6th week after flowering commences, i.e. approximately about the 14th week after planting.

(2) From this point it falls less rapidly almost to zero in the 13th week after flowering commences, i.e. when the plants are about twenty-one weeks old.

(3) The curve then rises rapidly again to another series of high values and then sinks again almost to zero. The curve is not so high in this part as in the first, and is not so regular.

(4) The curve is thus divided into two distinct portions: (a) a curve corresponding to the curve compiled from the average plants (explained and discussed later). Practically all the flowers in this part are produced on sympodia from the main axis, but the curve is not symmetrical because, after the date of the highest point, a few flowers begin to be produced from sympodia which spring from the vegetative branches : (b) a curve composed almost entirely of flowers from secondary branches.

(5) Inequalities of the flowering curves, i.e. sudden depressions, are probably the result of bud-shedding. These inequalities are shared by all the plots.

(6) It will be shown subsequently that the period of maturity of the Sea Island boll is about fifty-one days. Suggestions have been made from time to time that certain manures promote or retard maturity. If this were the case we should expect certain plots to flower earlier and produce modal values in their flowering curves earlier than other plots. This does not occur. The theory

finds no support from the flowering and bolling curves of the manurial plots. All the plots begin to flower at the same time, and subsequently the course followed by both flowering and bolling curves in all plots is similar. The highest point of both curves is attained at exactly the same time in every plot. The statement that certain manures promote or retard maturity is quite evidently not true of the light soils and heavy rainfall of St. Vincent.

(7) The bolling curves are low compared with the flowering curves, and the higher the flowering curve, the higher the bolling curve. The bolling curves are all similar in shape and possess depressions and modes which occur fifty to fifty-five days after similar depressions and modes in the flowering curves. Thus a depression in the flowering curves on October 2, is followed by a depression in the bolling curve on November 21, (i.e., about fifty days later), and the flowering depression of November 6 corresponds to the bolling depression of January 31. Similarly the summits of the flowering and bolling curves are separated by a fifty-five day interval. As will be shown subsequently, the time interval from flower to boll is about fifty-one days, which explains the 50-55 interval above referred to. It is apparent, therefore, that while a comparison between flowering and bolling curves affords valuable information in regard to loss suffered, yet in general the percentage of flowers which mature into bolls is about the same for each plot, irrespective of the different kind of manure applied. Furthermore, the bare yield of seed-cotton affords reliable information as to the relative value of different manures.

(8) All the bolls which mature are from the first part of the flowering curve. Internal boll disease is the factor chiefly responsible for the total loss of all flowers after December 11. The bolls from part two of the flowering curve are known in the West Indies as the 'second picking'. This is seldom obtained in St. Vincent, though in Barbados it often forms the principal part of the crop.*

Stainers appeared in overwhelming numbers towards the end of December. On February 10, 1,000 bolls apparently quite sound were taken from the manurial plots. Of these 993 were completely destroyed by internal boll disease. The percentage of sound bolls being only 0·7, it was decided to pull the plants up on February 15, and conclude the experiment.

(9) It appears from Table VI below that, taking the first part of the flowering curves as the only efficient part, and calculating the percentage of flowers produced during each five-day period—over 50 per cent. of the efficient flowers are produced in the 7th, 8th, 9th and 10th periods ending 12th, 17th, 22nd, and 27th of October, i.e. in twenty days—roughly a period of about three weeks.

These three weeks and the following three are thus the most important in the life-history of the plant, and we may safely conclude that good or bad weather conditions during that period (the 13th to 19th weeks after planting) will make the difference between a good and a bad crop.

*As used in Barbados the term often refers to the 'ratoon' crop, not here considered. (Ed. *W.I.B.*)

TABLE VI.

SHOWING PERCENTAGE OF FLOWERS PRODUCED IN DIFFERENT 5-DAY PERIODS OF THE FIRST PART OF THE FLOWERING CURVES.

Manure.	Plot.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
		NO. OF 5-DAY PERIOD.																		
ɒ manure ...	1	0·04	0·46	1·13	2·12	2·00	5·94	11·11	14·00	13·90	11·69	7·56	5·26	7·77	7·42	5·52	2·04	0·97	0·63	0·45
itrogen	2	0·13	0·70	1·38	2·59	2·24	6·61	12·53	14·60	14·60	10·56	7·13	4·67	6·90	6·13	4·61	2·48	1·05	0·76	0·48
ıosphate... ...	3	0·04	0·21	0·90	1·59	1·46	5·25	10·75	14·34	14·68	11·43	8·18	6·46	7·89	7·63	5·55	2·14	0·90	0·45	0·25
ɔtash	4	0·12	0·59	1·47	2·72	2·28	6·24	10·76	14·51	.1296	10·15	7·19	5·72	7·41	7·07	5·95	2·94	1·26	)·63	0·54
hosphate and potash	5	0·05	0·27	0·95	1·89	1·84	6·09	11·13	14·37	13·75	10·55	7·33	5·36	7·54	7·49	6·09	2·98	1·17	0·73	0·42
itrogen, phosph. × potash ...	6	0·21	0·90	0·21	3·37	2·92	7·23	12·95	15·35	13·63	9·47	6·78	4·19	6·10	6·20	4·57	2·08	1·05	0·65	0·36
otton-seed meal...	7	0·03	0·22	0·96	1·91	1·85	6·50	12·18	15·10	14·53	10·83	6·95	5·21	7·02	6·71	4·87	2·72	1·25	0·82	0·33
. S. M. × Phos-ɪhate and potash	8	0·09	0·42	1·30	2·38	2·16	6·26	11·13	14·41	13·14	10·60	7·63	5·35	7·00	7·20	6·52	2·86	1·13	5·03	0·34
	Av.%	0·09	0·47	1·04	2·32	2·08	6·27	11·57	14·9	13·9	10·66	7·34	5·28	7·20	6·98	5·46	2·53	1·09	1·21	0·39

During the 1916-17 season the period of maximum flower production was followed by the torrential downpours of late October and most of November, and the crop was practically ruined.

The Crop Records Series.

It will have been noticed that only about 12 per cent. of the flowers produced matured into bolls. The enormous loss implied needs explanation. The crop records series, i.e. intensive records from single plants, provide a considerable part of that explanation. The method adopted is simple. The fruiting branches of each plant are numbered from the base upward with small cambric labels, on which the required number has been written with indelible ink. The labels are affixed to the fruiting branch with a small ring of brass wire, at a point near to the main stem in such a way as to cause no injury to the tissues. Any boll, flower or bud, is referred to by two numbers. The first number refers to the number of the fruiting branch, and the second to the position on the fruiting branch. Thus 8·4 would mean a bud, boll or flower on the 4th node of the 8th fruiting branch.

It will be convenient to refer the reader to Plate 2. This is a practically continuous record of a single plant from October 10 to January 22. There are thirty-seven records similar to the one shown, and even from a casual inspection it seems that the principal cause of loss of crop is the shedding of bolls or buds. This fact obviates the necessity of giving the other plant charts in full, since a simpler form of diagram (see Plates 3-6) will show the main facts quite as well. In certain cases a node has flowered but its history was not completed at the time the plants were pulled up. All the bolls so left can be regarded with certainty as infested with internal boll disease.

These intensive records make it possible to analyse with a fair degree of certainty the various sources of loss, and these will be discussed one by one at this point. The form assumed by the flowering curve can be explained in the light of information derived from a study of single plants.

TO DETERMINE THE INTERVAL BETWEEN SUCCESSIVE FLOWERS ON A SINGLE FRUITING BRANCH.

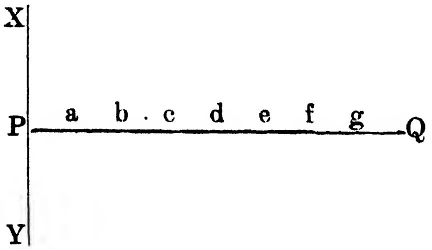

Fig. 2.

Imagine Fig. 2 to be a diagrammatic representation of a fruiting branch PQ., from the main axis XY. Then it may be taken as an invariable rule that the order of flowering is a, b, c, d, e, f, g, etc. If the growth of the plant is fairly uniform

there should be a certain average time interval between a and b, b and c, etc., and by examination of a large number of cases it should be possible to determine what these intervals are for the average plant.

A statistical investigation of the various intervals is presented in Table VII.

TABLE VII.

SHOWING VARIATION OF TIME INTERVAL BETWEEN FLOWERING OF SUCCESSIVE NODES.

Fruiting branches.	Nodes.	Days.													Total cases.	Average in days.
		3	4	5	6	7	8	9	10	11	12	13	14	15		
1 to 20	1 & 2	3	15	72	18	5	2								115	5·1
20 to 30	1 & 2	1	1	25	35	26	3	4	1						96	6·2
30 to 40	1 & 2			2	4	9	5	8	2						30	7·9
1 to 20	2 & 3		2	43	53	18	15	2							153	5·3
20 to 30	2 & 3			5	10	21	10	2	-	1					49	6·9
30 to 40	2 & 3					2	6	2	-	1	1				12	8·6
1 to 20	3 & 4		1	3	29	30	17	9							89	7·0
20 to 30	3 & 4				1	5	9	2	-	-	-	-	1		18	8·0
1 to 20	4 & 5		1	2	10	4	2	2							21	6·5
20 to 30	4 & 5					1	3	2							6	8·2
1 to 20	5 & 6		1	3	11	22	9	4	-	-	-	-	-	1	51	7·1
1 to 20	6 & 7			2	5	8	4	1	1						21	7·0
1 to 20	7 & 8				1	4	2	2	1						10	7·8

From this table it is seen that, taking any fruiting branch from 1 to 20, the 2nd node will flower not less than three days after the 1st node and not more than eight days, while it will most probably flower in five days.

The following facts are immediately apparent:—

(1) The time interval between the flowering of two adjacent nodes increases as the distance from the central axis is increased.

(2) The interval between two adjacent nodes increases with the distance from the lowest fruiting branch.

(3) The increase is in general of quite a definite nature.

TO DETERMINE THE INTERVAL BETWEEN 1ST NODES ON SUCCESSIVE FRUITING BRANCHES.

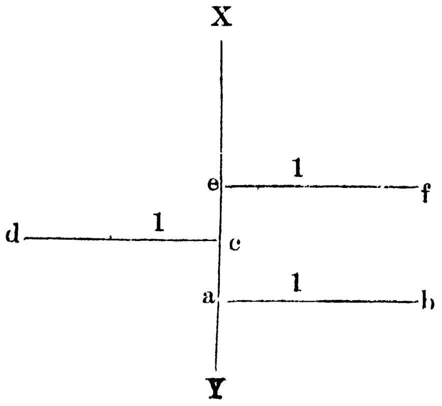

FIG. 3.

Suppose XY to be the main axis of a given plant and ab, cd, ef, etc , to be successive fruiting branches. Then in general node 1 on cd will flower later than node 1 on ab, and node 1 on ef later than node 1 on cd. Investigating the question statistically we obtain a table similar to the preceding one.

TABLE VIII.

SHOWING INTERVAL BETWEEN 1ST NODES ON SUCCESSIVE FRUITING BRANCHES.

Days interval.

Fruiting branches.	0	1	2	3	4	5	6	7	8	9	10	Total cases.	Average No. of days.
1 to 20		6	35	51	11							183	2·2
20 to 25	1	1	16	31	33	12	2	1				97	3·5
25 to 30		3	2	12	11	7	2	1				38	3·7
30 to 40	1	-	2	5	11	10	4	3	1	-	1	38	4·6

CONCLUSIONS :—

(1) For the first twenty fruiting branches the variation in interval is comparatively small.

(2) The range of variation is greater as the distance from the first fruiting branch increases.

(3) The average number of days increases with the distance from the first fruiting branch.

Now the reason for the increase of interval between nodes, and between successive fruiting branches is obviously that the rate of growth of the main axis slows down as the plant gets

older, and the rate of growing of any particular fruiting branch must slow down as the 'senescence point' is approached.

ABORTION OF FRUITING BRANCHES. The manner of development of a sympodium or fruiting branch is explained well by W. Nowell [5]. The following quotation is taken from this source: 'Such a branch originates from one of the two buds at a node on the main stem or on a vegetative branch. Its first section (internode) grows out to nearly or quite its full length while the internodes to follow are quite undeveloped. At its first node a leaf is borne, and the original axis then terminates in a flower. At the base of the first leaf there are again an axillary and an accessory bud. One of these buds grows out to carry forward the branch, forming the second section, which ends like the first in a leaf and a terminal flower. Again a bud grows out to continue the branch, and the same method of growth is repeated indefinitely.'

When elongation of the fruiting branch has ceased owing to its growth rate having become zero, one would imagine that in an ideal environment the terminal bud with the adjacent flower bud might remain dormant for an indefinite period. Sooner or later however, in every case, the terminal bud turns yellow and drops, and the fruiting branch becomes 'aborted'.

It has been observed that during periods when large numbers of buds and bolls were being shed, the terminal buds of sympodia were shed also, and conversely when there was little shedding of buds and bolls the terminal buds did not abort. Thus abortion of sympodia may be dealt with under the general heading of shedding.

THE NODAL NUMBER OF FRUITING BRANCHES. From the crop records a table can be constructed in which the number of nodes per sympodium in Sea Island cotton is given.

Table IX.

SHOWING NUMBER OF NODES PER FRUITING BRANCH.

No. of fruiting branch.	0	1	2	3	4	5	6	7	8	9	10	Cases.	Average.
1		2	11	4	-	-	-	-	3	1		22	3·2
2		3	5	5	2	1	2	2	2	1		22	4·1
3			6	3	2	3	1	5	1	1		22	4 6
4			7	1	1	2	3	4	1	3		22	5·1
5			1	3	2	1	5	5	4	1		22	5·9
6				1	2	2	7	5	5			22	6·3
7			1	3	2	2	7	3	2	2		22	5·7
8			1	0	3	1	10	4	3			22	6·0
9					1	6	6	8	–	-	1	22	6·1
10				1	3	7	7	3	1			22	5·5
11				1	3	7	9	2				22	5·4
12					7	5	4	4	1	1		22	5·5
13				2	4	6	7	2	1			22	5·3
14					7	8	5	2				22	5·1
15				1	7	7	4	2	-	1		22	5·1
16					8	7	4	2	1			22	5·1
17				1	12	4	3	1				22	4·5
18				3	7	7	3	–	1	–	1	22	4·9
19					9	8	3	2				22	4 9
20				4	9	6	2	1				22	4·4
21				2	14	4	1	-	1			22	4·4
22			1	2	13	4	2					22	4·2
23		1	1	6	9	2	2	1				22	3·9
24			2	7	9	2	1	–	1			22	3·9
25			5	7	6	4						22	3 4
26		1	8	5	7							21	2·9
27	2	5	2	8	3	1	1					22	2·5
28	3	4	4	5	2	1						19	2·1
29	3	5	6	3	1	–	1	1				20	2·2
30	2	6	5	4	2	1						20	2 1
31	5	5	1	3	1	1						16	1·6
32	4	4	2	5	1							16	1·5
33	2	6	3	3	1	1						16	1·9
34	1	2	5	2	4							14	2·4
35		3	4	2								9	1·9
36		4	2	3								9	1·9
37	1	2	–	3								6	1·8
38		1	1	2								4	2·3
39				2								2	3 0
40			1	1								2	2·5
41	1	1										2	·5

CONCLUSIONS. (1) There is a tendency for the first four fruiting branches to abort early. There is a considerable range. In fruiting branch 1, in particular, there is distinct bimodality from which it may be concluded that certain plants have little

tendency to abort at nodes 1, 2 or 3, but produce the maximum number, i.e., the great variation in range in this case is probably caused by the fact that some of the plants are endowed with different hereditary tendencies.

(2) Apart from the tendency to early abortion of the lower fruiting branches in some plants, there is a general decrease in the number of nodes as the top of the plant is approached.

(3) The apparent partial recovery after fruiting branch 32 is explainable. The plants passed through an exceptionally wet November and recovered somewhat in December. With the facts that we now have at our disposal we are in a position to construct the 'average plant of the manurial series' as follows.

From Tables IX and XI two curves have been constructed: (a) the curve of flowering of the average plant, (b) the curve of the number of nodes per fruiting branch in the average plant. These will be seen in Plates 7 and 8.

THE FLOWERING CURVE OF THE AVERAGE PLANT.

CONCLUSIONS :—

(1) The curve rises more or less gradually to a mode in the 6th week, and then falls at approximately the same rate.

(2) Most flowers are produced in the 5th, 6th and 7th weeks.

(3) The superimposed curve compiled from a single plot in the manurial series shows a mode also in the 6th week. The reason for the form assumed by the flowering curves of the manurial plots is now clear. That most flowers are produced in the 6th week after flowering commences is a necessary consequence of the fixed values of modal interval and time interval between the first node in successive fruiting branches. It is undoubtedly the case in the West Indies that these intervals remain almost the same throughout the year. Rate of growth is mainly conditioned by temperature, and in the smaller islands of the West Indies the range of temperature during the year is extremely small.

(4) The flowering curve of the average plant takes cognizance only of flowers produced on the sympodia of the main axis, and ignores bud-shedding. The shedding of buds may be the cause of considerable distortion of the flowering curve, and it is fairly safe to assume that the lowness of the plot curve in the 1st, 2nd, 3rd, 4th, and also in the 8th and 9th weeks is due entirely to loss by bud-shedding.

(5) The average plant in this particular manurial plot (1 a) is inferior to the calculated average plant.

Table X.

THE AVERAGE PLANT OF THE MANURIAL SERIES.

FB.	Nodes.	Time of flowering.					
1	3	1	6	11			
2	4	3	8	13	20		
3	5	5	10	15	22	29	
4	5	8	13	18	25	31	
5	6	10	15	20	27	33	40
6	6	12	17	22	29	35	42
7	6	14	19	24	31	37	44
8	6	17	22	27	34	40	47
9	6	19	24	29	36	42	49
10	6	21	26	31	38	44	51
11	5	23	28	33	40	46	
12	6	25	30	35	42	48	
13	5	28	33	38	45	51	
14	5	30	35	40	47	53	
15	5	32	37	42	49	55	
16	5	34	39	44	51	57	
17	5	36	41	46	53	59	
18	5	39	44	49	56	62	
19	5	41	46	51	58	65	
20	4	43	48	53	60		
21	4	46	52	59	67		
22	4	50	56	63	71		
23	4	53	59	66	74		
24	4	57	63	70	78		
25	3	60	66	73			
26	3	64	70	77			
27	3	68	74	81			
28	2	72	78				
29	2	75	81				
30	2	79	85				
31	2	84	92				
32	2	88	96				
33	2	93	101				
34	2	97	105				
35	2	102	110				
36	2	107	115				
37	2	111	119				
38	2	116	124				
39	3	120	128				
40	3	125	133				
41	2	129	137				

Note. The numbers under time of flowering allude to days after first flower, e.g., 77 means the 77th day after the first flower. From Table X it is possible to construct Table XI in which is shown the number of flowers opening in each week after flowering commences (reduced to per plant per day).

Table XI.

SHOWING RATE OF FLOWERING OF AVERAGE PLANT.

Week.	No. of flowers.	Per day.
1	4	0·6
2	9	1·3
3	10	1·4
4	13	1·8
5	17	2·4
6	18	2·6
7	17	2·4
8	13	1·8
9	11	1·6
10	8	1·1
11	7	1·0
12	6	0·9
13	2	0·3

CURVE OF NUMBER OF NODES PER FRUITING BRANCH. The number of nodes per fruiting branch is the result of the interaction between the hereditary tendencies of the plant and the environment. In Sea Island cotton the maximum number of nodes, so far as I have observed, is 13; in Upland 14; in Seredo Type 2, I have seen as many as 30, while in certain types, notably Kidney cotton (*G. brasiliense*, Macf.) I have never seen more than 5. It is quite clear that a group of factors governs this character, although it is to be admitted that unfavourable conditions can cause great distortions. There doubtless exist a number of different strains, each with its own ideal curve of nodes per sympodium, and the isolation of the best types will prove in the future an important part of selection work with cotton.

THE FLOWERING CURVE OF THE CROP RECORDS PLANTS IN THE MANURIAL SERIES. A study of the flowering curve (see Plate 9) compiled from the twenty-one plants studied in detail reveals the fact that there is great variation in the numbers of flowers produced from day to day. Certain days stand out as good days; others as very bad. The curves for the no-manure and complete manure plots have been drawn on the same plate, and it will be seen that the depressions and elevations are shared by every plant in the field. It remains now to investigate as far as possible the reason for this.

Now October 22 and 25 are, compared with their neighbours, days when flowering was good, whereas the 21st and 24th were poor days. Some clue to the reason has been obtained, but curves of the growth rate of the plants are not available, and these are necessary for a full discussion of the question. Now all the flowers which open on October 17 will possess a node beyond them which ought to produce a flower, and we know from the information given previously that this interval should vary from, say, three to eight days. In Table XII it will be seen

that taking the nodes which follow October 10, two flower in four days, one in five days, two in six days, and one in seven days. The other days are to be interpreted similarly. Now the flowers which follow most of the days possess a distinct modal value, e.g. those following October 17 have a mode on the 5th day after. In all cases the modal value is at 5, 6, or 7. In certain cases there is coincidence of two modes on the same day, and on that day we find a high flowering rate. For October 19 the mode is 6; for October 20 the mode is 5. The two unite on the 25th, a day which has a very high rate of flowering. Some days have no mode at all, e.g. the 21st, 24th, 26th, and 29th of October. All these days are low flowering. It may therefore be concluded that certain factors operate which tend to bring the majority of the flowers which follow two successive days into flower on the same day. In the absence of exact measurement of the rate of growth of the main axis, sympodia, and flower buds, it would be unwise to pursue the question further.

Note. Some of the nodes following each day will fail to flower owing to bud-shedding, and it might be thought that the explanation of the low flowering rate of certain days might be found here. Bud-shedding certainly has an effect, but the main clue is afforded by the above discussion.

TABLE XII.

SHOWING TIME OF FLOWERING OF NEXT NODE ON FRUITING BRANCH.

Average.	Date.	Frequency of flowering of next node on following dates. Oct.																		Nov.							Mode.
		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6	7	
	Oct.																										
5·3	10	2	1	2	1																						
5·8	11		1	2	5	2																					6
5·5	12				8	6	1																				5
5·6	13				1	5	4	2																			6
6·0	14						2	7	2																		5
6·0	15						3	2	2	4	2																6
6·1	16							3	4	6	8	1	1														7
5·6	17							1	6	16	11	4	4														7
6·1	18									1	8	6	3	4	1												5
6·3	19											3	12	5	3												5
6·0	20												11	6	7	3											5
6·1	21													5	9	8											6
6·4	22													1	2	9	7	3									6
5·9	23															10	4	5	0	1							5
6·1	24														1	0	1	4	1	2							5
6·0	25																	10	6	6	1	1					5
6·0	26																		2	5	2						6

INTERVAL BETWEEN FLOWER AND MATURE BOLL. It has been possible to obtain for a large number of cases the period

which elapses between the opening of the flower and the time of opening of the boll from that flower. The results are set forth in Table XIII.

Table XIII.

MATURING PERIOD OF BOLLS (SEA ISLAND).

Days.

	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	Cases.	Days average.
A			1	...	1	1	2	6	8	32	32	25	24	7	4	1							144	51·2
B					2	..	...	..	3	9	12	6	1	4	3	1	...	...	...	...	1		44	50·8
C	1	...	1	1	...	...	4	4	7	10	7	16	7	5	1	1	...	1					66	50·8

A. Healthy bolls.
B. Bolls diseased ⅞, ⅝ or ½.
C. Bolls diseased ¼ or 0.

From the above table it will be seen that the modal value for healthy bolls falls at fifty or fifty-one days, and most will certainly open between forty-nine and fifty-three days. In regard to the diseased bolls, no attempt has been made at distinguishing between those affected by internal boll disease and those by external boll disease. Many bolls are affected by both diseases so that in practice a distinction is very difficult. The average period of maturity is much the same for the diseased bolls but the range is wider, owing to one or two very erratic specimens which have opened either very early or very late. It is interesting to compare the maturing period of the bolls of Southern Cross, a variety of Upland. It is set forth in the table below.

Table XIV.

MATURING PERIOD OF BOLLS (UPLAND).

Days.

40	41	42	43	44	45	46	47	48	49	50	51	52	Cases.	Days average.	
						1	1	1	3	–	1	3	10	49·5	Strong vigorous plants
						3	1	2	2	3	2		13	48·5	in rich ground.
1	–	1	–	2	–	3	–	2	1				10	45·3	Dwarfed plants in
				2	3	3	1	1	1	1			12	46·3	poor ground.

The average period of maturity is distinctly lower than Sea Island. The last two plants have a lower average than the first

two. I believe the variety to be a pure strain but would not too hastily ascribe the earlier period of maturity in the dwarfed plants to their environmental conditions. Balls's conclusions in regard to the maturing period of bolls in Egypt are summarized in the following quotation : [2] 'This period is variable, its length being in the first place specific. At Cairo King Upland has a mean period of 42 days, Egyptian Sultani of 51 days, Egyptian Afifi of 48 days. P.E. 3 per cent. The maturation period is 8 days longer in the middle Delta than at Cairo.'

Thus the Egyptian results do not differ very appreciably from those in St. Vincent, allowing for temperature differences.

BOLL-SHEDDING. It has been demonstrated that the chief cause of loss of crop is due to the shedding of bolls and buds. Nowell [5] states, 'It has been established that shedding occurs when from any cause whatever the amount of water taken in by the roots falls short of that which is given out by the leaves. Undue exposure to wind, caking of surface soil, drought, root interference, root pruning by cultivation, excessive vegetative growth brought on by rain during the flowering period, and the asphyxiation of the roots in water-logged soil are all capable of bringing about bud-shedding.' The soundness of these remarks is fully borne out by the crop records.

It is of interest to determine the period when the bolls are in the most susceptible period for shedding. Table XV presents the data in statistical form.

TABLE XV.

SHOWING PERIOD AT WHICH BOLLS ARE MOST SUSCEPTIBLE TO SHEDDING.

Days after flowering.

	1-7	8-14	15-21	22-28	29-36	37-42	43-49	Total.
No. shed	143	161	116	43	14	1	1	479

It will be seen that during the fifty-one days' life of the boll the first three weeks are the most susceptible, and broadly speaking it seems that if a boll is able to stay on the plant for twenty-one days there is considerable probability that it will arrive at maturity. It will be shown subsequently that boll-shedding is aggravated by the fact that if a boll be attacked by disease in such a way as to interfere with the normal conduction of food material into the boll, the latter is rendered very susceptible to those conditions which induce shedding, and thus we find that in very wet or very dry periods, enormous numbers of almost full-grown diseased bolls will be dropped. Thus boll-shedding may be sub divided into (a) natural shedding of sound bolls usually not more than ten days old, (b) shedding of bolls attacked by internal boll disease or external boll disease. These bolls may

be much older than those naturally shed. It may be thought that the shedding of diseased bolls does not matter particularly, but it is important because the shed boll may contain one or two healthy locks which would be gathered in the ordinary course of events.

Any cause which extends the period of susceptibility is bound to cause great loss of crop, particularly as it is somewhat unusual in St. Vincent for a boll to go through its first twenty-one days without meeting conditions which tend to cause shedding.

Comparison between St. Vincent and Egypt in regard to Shedding.

The average yield of lint in Egypt is stated to be about 450lb. to the acre—far higher than any other cotton-growing country. Information in regard to the loss caused by shedding in Egypt has been given by Balls, and it will be instructive to compare the position in Egypt with that of St. Vincent. Balls says: 'The organs shed by the plant are chiefly flowers shed three or four days after opening, and hence only described as bolls by courtesy. Ripening bolls up to 2 centimetres in diameter may be shed, but this is less common.' Table XV gives only the number of bolls shed in the first seven days after opening, but it may be said that out of the 479 bolls which dropped, 74 or roughly 16 per cent. dropped in the first four days after opening. Thus we see that in general, the loss of crop in St. Vincent through shedding of young bolls is comparatively unimportant compared with that caused by shedding of older fruits. Now, according to Balls, boll diseases are almost unknown in Egypt, whereas in St. Vincent they are the chief agents responsible for the heavy shedding of bolls.

Again it is stated by Balls: (3) 'For some reasons which are not yet understood, the open flower is extremely liable to "shedding" .... The shedding of older fruits is much rarer.' Again he says: 'It seems to have escaped notice that the shedding takes place almost entirely in the flower stage .... The flower stage is thus extremely liable to shedding, possibly for reasons connected with the chemical side of pollination, or with the greater transpiration from the open flower.'

In St. Vincent the shedding of open flowers is so rare that it may be ignored as a source of loss. No case of an open flower being shed was recorded in the whole of the crop records series. Occasionally I have seen isolated examples on estates in very dry periods.

Balls devotes so little attention to bud-shedding that we may assume that it is not an important source of loss in Egypt. In St. Vincent the loss from bud-shedding is often very great, particularly when heavy rains are experienced about the 6th to the 12th weeks after planting. Then the common type of Sea Island plant on estates is similar to the diagrams of I. 11. 1. and I. 11. 2. on Plate 6, where most of the early buds have been shed.

The loss in Egypt through shedding is stated to be about 40 per cent. Assuming a loss of only 40 per cent. in St. Vincent

we should get an average yield in the complete manure plots (8) of 1,558lb. of seed-cotton per acre, equivalent to 390lb. of lint.

The Relative Efficiency of Flowers Produced on Different Parts of the Plants.

Now if as Balls says, the cause of shedding of a particular boll be due to a shortage of water for that boll, it seems likely that bolls on the outermost nodes will be most liable to shedding, and further it follows that flowers may have very different relative values according to whether they are produced in places where they are liable to be shed or not. The figures available show that this is the case. In Table XVI will be found the results of an examination into the effect of the position of the flower on the chance of maturing.

Table XVI.

SHOWING EFFECT OF POSITION OF FLOWER ON CHANCE OF MATURING.

No. of node.	No. of flowers.	No. of bolls.	Per cent. bolls to flowers.
1	230	76	33
2	185	70	37·8
3	172	65	37·8
4	134	20	14·9
5	116	17	14·7
6	50	5	10·0
7	15	0	0
8	4	0	0
9	...	...	...

Although the results are by no means complete, it is certainly the case that the value of flowers on nodes 1, 2 and 3 is more than twice as great as those on later nodes. It is apparent that nodes 6, 7 and 8 are practically valueless. Nodes 2 and 3 show the same percentage of flowers maturing into bolls, a greater percentage than that of node 1. If a further dissection of relative values were made it would no doubt be established that the value of node 1, 2 or 3 would vary according to the fruiting branch. Thus a flower produced at the very top of the plant very seldom matures a boll, while those near the middle usually do. The figures obtained so far are suggestive, and indicate the necessity for further research. The main point is that for any particular planting distance there are certain flowers more efficient than others, the efficiency being measured by the chance of maturing into a boll. If nodes 5 to 8 are of little value, it is obviously a waste of energy on the part of the plant to produce them.

To prevent their production the plants could be spaced clos er. Will closer planting reduce the efficiency of flowers on the first three nodes to any extent; and if so, by how much?

What we have to aim at is to find that planting distance which is favourable to the production of most flowers of optimum efficiency. The efficiency of a flower must vary from season to season, but I imagine that the relative efficiencies of different flowers on the same plant must change but little.

THE SHEDDING CURVES. To return to the subject of shedding; Balls has given on page 68 of 'The Cotton Plant in Egypt', shedding curves of the field crop at Giza 1910, compiled from 1,300 plants collected weekly. The chief differences between Balls's curves and ours are these: (a) bud-shedding is much more important in St. Vincent than in Egypt; (b) flower-shedding is quite rare in St. Vincent, whereas it is a serious source of loss in Egypt.

Balls's direct curves of shedding are from weekly collections; ours are from direct daily observations of a small number of single plants. It would be impracticable in this island to make weekly countings of buds shed. In the first place many of the buds shed are not more than 2mm. in diameter and would escape notice even if they remained undecomposed. Under the conditions of high relative humidity in the tropics, decomposition of vegetable matter takes place with extreme rapidity. If buds of so small a diameter are shed in Egypt, it is probable that Balls's bud-shedding curves are too low.

There are three ways of compiling data for a shedding curve:—

(1) Counting the number of bolls, flowers or buds which have dropped on the ground.

(2) By subtraction, e.g. 'Since the mean for the standard Afifi strain at Cairo lies at 48 days $\pm$ 3 per cent. we shall not introduce any serious error if we plot the mean shedding curves of this strain by subtracting bolling from the flowering of seven weeks previously. Such a subtraction result is not precise, but it is very useful in cases where direct shedding records have been impossible.'

(3) By daily examination of a group of plants and recording all buds or bolls shed during the preceding twenty-four hours.

Now, under St. Vincent conditions the first method has been stated already to be impracticable. The second would give not a shedding curve but a 'loss curve', since cryptogamic disease plays a tremendous part in preventing bolls from maturing. The third is the only precise method, and is the one which I have adopted. The subtraction curve in Egypt gives a great deal of information as to the conditions which induce shedding, since cryptogamic disease is unimportant as a source of loss in that country. In this island we should only be able to interpret a mode in the shedding curve as signifying that flowers opening on a particular date met with unfavourable conditions which caused either shedding or total destruction by disease. In the case of the soft-rot disease caused by a species of Phytophthora, the bolls are seldom shed, but remain on the plant in a hard and dried-up condition. The subtraction curve would afford us relatively little information as to the effect of meteorological conditions on any particular phase of loss.

In Plate 10 will be found the direct shedding curves of bolls and buds, compiled from plants in the crop records series. The data cover the period from October 25 to January 13. On the same plate will be found a graphical presentation of rainfall and relative humidity during the same period.

The heavy shedding throughout the latter part of October and the whole of November will be noted. The general correspondence between the two shedding curves is most marked. The rainfall curve shows extremely heavy precipitation almost throughout November, and it will be seen that the shedding is heaviest in the neighbourhood of the heaviest downpours. It would be unwise to enter into a more detailed discussion as to the more particular causes of the heavy shedding on certain days and the comparatively light shedding on other days, since accurate information on the amount of soil moisture and its permissible limit and on amount of wind, sunshine, etc., is wanting.

This much may be said, that as far as the evidence goes, the heavy shedding in October and November was due to heavy rainfall during that period, which caused root asphyxiation. Absorption was thus interfered with and shedding induced. A point to notice in connexion with this subject is that two things are necessary to produce a high mode in the shedding curves :—

(1) A large number of bolls or buds in the most susceptible stage for shedding.

(2) Water-shortage for those particular buds or bolls.

If there is no shedding on a particular day it may signify that the number of buds or bolls in a susceptible stage is small, i.e. previous unfavourable conditions may have caused every available bud or boll to drop. The absence of shedding does not necessarily imply that the shedding conditions are not present.

RELATION OF CRYPTOGAMIC DISEASES TO YIELD. What is definitely known of the fungoid and bacterial diseases of Sea Island cotton in the West Indies has been summarized by Nowell.[5] The mycology of cotton diseases is at present not well understood, but I shall, I believe, not be contradicted if I put the following down as the most serious diseases of cotton in St. Vincent :—

(1) The Internal Boll disease.
(2) The External Boll disease.
(3) The soft-rot or Phytophthora disease.

THE INTERNAL BOLL DISEASE. Now, as will have been noted from the plant diagrams (see Plates 3 to 6) the internal boll disease was a serious source of loss throughout the season. It has been shown to be dependent for its spread on certain plant bugs, notably the cotton stainer (*Dysdercus delauneyi*, Leth.,) *Nezara viridula*, and probably also *Edessa meditabunda*. Fabr. During very wet weather the disease (which may be due to fungi or bacteria or both) assumes a bacterial phase, while in drier weather the fungoid phase is predominant. During the season under review cotton stainers were in the plots from the time of planting onwards, having spread from silk-cotton trees in the neighbourhood. Hand collecting was practised throughout the season

and no increase was noted in the number of stainers until the middle of December, when they appeared in overwhelming numbers quite suddenly. By the end of December it was scarcely possible to find a boll unaffected by the internal disease.

It may here be reiterated that with cotton stainers present in large numbers cotton growing in St. Vincent becomes impossible. A few stainers, it must be remembered, can impart disease to a large number of bolls. The impracticability of hand collecting as a means of controlling the cotton stainer was thoroughly demonstrated during the past season.

The bacterial and fungoid phases of the disease appear to be equally destructive. Thus while humidity conditions apparently determine the distribution of the two phases, the damage caused by the disease does not lessen in dry weather. The problem of the control of the cotton stainer has received great attention, and it is hoped that the recent legislation for the destruction of the wild food-plants (*Eriodendron anfractuosum* and *Thespesia populnea*) will relegate this pest to a position of minor importance.

THE EXTERNAL BOLL DISEASE (*B. malvacearum*). In regard to this disease, presumably due to *Bacterium malvacearum*, the relative humidity of the atmosphere plays an important part in regulating its distribution and the amount of loss caused by it.

My experience of cotton growing in dry islands (St. Croix and the Southern Grenadines) and in an island of heavy rainfall such as St. Vincent, leads me to believe that the amount of destruction wrought by the disease is quite directly related to humidity. In St. Croix there is little damage by the disease. It appears in wet weather but is unable to make much headway when less humid conditions prevail. In the Southern Grenadines the disease is quite unimportant as a source of loss.

As has been stated earlier, much of the boll-shedding was due to this disease and to the internal boll disease. It was found in practice difficult to disentangle the two, so that when shedding due to disease is alluded to, one or both diseases is meant.

THE SOFT-ROT OR PHYTOPHTHORA DISEASE. The dependence of this disease on high humidity is shown by means of the graph on Plate 11. In the crop records the dates were taken when bolls were first noticed to be badly attacked. It will be seen that previous to the week ending November 16 no cases of soft-rot were recorded, but during that week and the next two a large number of bolls were attacked. The number of attacked bolls then fell off rapidly and no cases were recorded after the week ending December 28. The humidity curve was compiled from the wet and dry bulb readings taken at 9 a.m. each day. The instruments were kept in a Stevenson screen. The readings only give an approximate idea of the humidity conditions in the neighbourhood of the experimental plots and are certainly too low for the first two weeks in November. During that period the rainfall was so heavy that water was standing between the rows for some days, and the relative humidity on these occasions must have been near the saturation point. On November 2, 3, and 4 the relative humidity in the Stevenson screen was calculated to be 89, 85, and 95 per cent., respectively.

The disease is most virulent, and once a boll is attacked it produces no cotton whatever. Attacked bolls usually wither and dry on the stem. Enormous damage was done by the soft-rot disease during November.

RELATION OF BOLL DISEASE TO CAUSE OF DROPPING. On November 16, a time when large numbers of bolls were being shed, a number were collected just as they were dropping from the plants, and classified as follows :—

Affected by Internal Boll disease ...	160 or 64 per cent.
Affected by External Boll disease ..	53 or 21 „ „
Healthy bolls ...	37 or 14·8 .. ..

This shows that most of the boll-shedding during a very wet period was due to disease. All bolls classified under Internal Boll disease had that disease and no other. and it may therefore be concluded that cotton stainers are an even more serious source of loss than was before imagined.

On the light soils of St. Vincent the loss of healthy bolls through shedding is unimportant compared with that from disease.

NOTES ON SOME MISCELLANEOUS PLANT DIAGRAMS.

The plant diagrams on Plates 4, 5, and 6 require some explanation.

KIDNEY (*G. brasiliense*, Macf.). This type is apparently indigenous to St. Vincent. The diagram shows well the early abortion of the fruiting branches, characteristic of this species. It will be noticed that the number of bolls which matured is large in proportion to the number of flowers produced. The plant was growing in an isolated place and suffered very little from the attacks of cotton stainers.

UPLAND. The four Upland diagrams, of the variety Southern Cross, illustrate the effect of subjecting the plants to different environments. Plants (1) and (2) were grown in deep rich soil; (3) and (4) in poor shallow soil. The first two plants produced a much larger number of flowers but the shedding was greater. The three Cauto-Upland hybrids are interesting as showing the hereditary nature of the number of nodes per fruiting branch. Cauto is similar to the Kidney cotton and never produces more than six nodes on the fruiting branch. It is apparent that the habit of producing a large number of nodes per fruiting branch is dominant, and no exception to this rule has been noted in the very large number of different hybrids which have been under observation during the past season. Plants (1) and (2) of the Cauto-Upland Cross were grown in poor and shallow soil adjacent to Uplands (3) and (4),) while plant (3) was planted in deep rich soil. The greater shedding of plant (3) is most pronounced.

SEA ISLAND. Plants I 11. 1, and I 11.2 show the effect of continued wet weather at the commencement of the flowering period. Planted at the end of August they should have come into flower at the end of October, but owing to the large amount of bud-shedding on the lower fruiting branches the first flower

did not appear till a month later. This shedding ceased abruptly when drier conditions set in, and the sharp transition is shown well on the diagrams of these two plants. Plants (37) and (38) were planted at the beginning of November. They escaped the heavy rains, for no flower buds had yet formed. These two plants grew to a height of about 3 feet. Very few buds were shed and practically all the boll-shedding was due to the internal boll disease. Note that scarcely a single boll opened normally, the above disease being responsible.

General Considerations.

From what has been said it is clear that the loss of crop suffered by St. Vincent planters year after year has been due chiefly to shedding caused through heavy rainfall and complicated by fungoid and bacterial disease. The plant diagrams of I 11.1, and I 11.2 are characteristic of the June and July planted cotton, practically half the crop being lost through bud-shedding and the remaining half subject to attack by diseases owing their virulence to the usual heavy rains. Previous experience has shown that unless the majority of the bolls have matured by the middle of December there is little chance of obtaining a crop. Late planted cotton is usually of the type of plants 37 and 38, showing little bud-shedding, but a large number of bolls, the latter being invariably spoiled through internal boll disease. Planters have therefore avoided planting their cotton late. If the recent legislation against the food-plants of the cotton stainer has the desired result of relegating that pest and the internal boll disease to a position of minor importance, there is no reason why the loss hitherto suffered unavoidably through heavy rainfall should not be largely diminished by sowing the seed, say, at the end of August or even in September. The validity of the contention that better results will in the future be obtained from later plantings must be placed on a sound experimental basis by the Agricultural Department before planters are advised to change the time of planting to which they have been accustomed.

It will have been seen that the plants themselves are not responsible for the low yield. Their innate capacity for bearing a large crop cannot be doubted ; it is the conditions that have been at fault, and it follows that the statements which have been made from time to time that the plants have 'deteriorated' are incorrect.

The possibility of controlling the cryptogamic diseases of cotton by means of fungicides must now be considered. In a recent bulletin of the South Carolina Experiment Station ([8]) will be found an account of spraying experiments against the Angular Spot disease, and it is claimed that six sprayings during the season will control this disease to the extent of 98 per cent. It will therefore be necessary in the future to confirm this statement by repeating the experiment under St. Vincent conditions, but it is feared that the results will not be so good as those obtained in South Carolina. Difficulties which can be foreseen are the continuous rains which may make spraying impossible for days together, the difficulty of wetting the surface of the boll com-

pletely, protected as it is by the involucre of bracts, and the rapidity with which the young leaves unfold while the plant is in full growth.

In regard to the improvement of yield by means of the breeding of disease-resistant sorts, it will be recollected that the chief variety of Sea Island cotton grown in the West Indies is the 'Rivers' variety, originally a single plant selection made in the Sea Islands against the 'wilt' disease. The 'Rivers' type is said to be rather susceptible to the angular spot disease (*B. malvacearum*). It might be expected that the chances of finding a type resistant to angular spot in this variety would be very remote. Thus we find that after many years' work the search for a resistant variety in the West Indies has met with no success. Another point to consider is that the strains of cotton in most of the islands have been developed by the pedigree system of selection, and it may be assumed that as these strains obviously breed true to absence of resistance, it is of no use selecting from them with the hope of isolating a resistant variety.

Again, it is most important to point out that the breeding of new cottons is by no means an easy matter. As Balls ([1]) has said: 'Cotton is one of the least suitable plants for genetic investigation, and any university working with it would require heavy subsidies, which in their turn would demand results. When each plant requires a square metre of ground, when every flower used for seed has to be artificially prevented from crossing by bees, and when all the field work must be carried out in a sub-tropical climate, the genus cannot be regarded as a convenient one for the purpose, even if we disregard the trouble which ginning involves in the handling of pedigree seed ..... The maintenance cost is too great for any university, in proportion to the results obtained the time and skill required are too great to make such work a paying proposition for any commercial body.'

Certain of the types of cotton grown at the Experiment Station show resistance to the angular spot disease which is quite definitely genetic. What must be aimed at is to synthesize a new type of cotton, combining the desirable qualities of Sea Island cotton with the disease resistance of these otherwise undesirable varieties. Such a deliberate synthesis is no mean task, and we are informed by Balls that in Egypt he only accomplished the first synthesis of a desired type of cotton after nine years of work.

In conclusion I wish to extend my thanks to Mr. Floris Simmons, Foreman of the Experiment Station, for his services in connexion with the compilation of the flowering and bolling records.

Explanation of Symbols in Plate 2.

B. signifies that a boll was present when observations began.
F. signifies that a flower opened.
B.S. „ Bud-shed.
D. „ Dropping of Boll.
D. (by itself) „ „ „ or Bud.
O. signifies Boll opened.
O. $\frac{1}{3}$, $\frac{2}{3}$, etc. Boll opened but was only $\frac{1}{3}$ or $\frac{2}{3}$ good, the rest being spoiled or rotted by disease.
Ax. = The Axillary Bud.
E.B.D. = The External Boll disease.
I.B.D. = The Internal Boll disease.
P. = The Phytophthora disease.
Ab. = The abortion of the terminal bud which carries on the fruiting branch.

Explanation of Symbols in Plates 3-6.

s Bud-shed.
S Boll shed
D Bud or Boll shed.
a Aborted.
O Boll opened normally.
I Attacked by I.B.D.
E „ „ E.B.D.
P „ „ Phytophthora.
B Boll still on plant at time when diagram was compiled.

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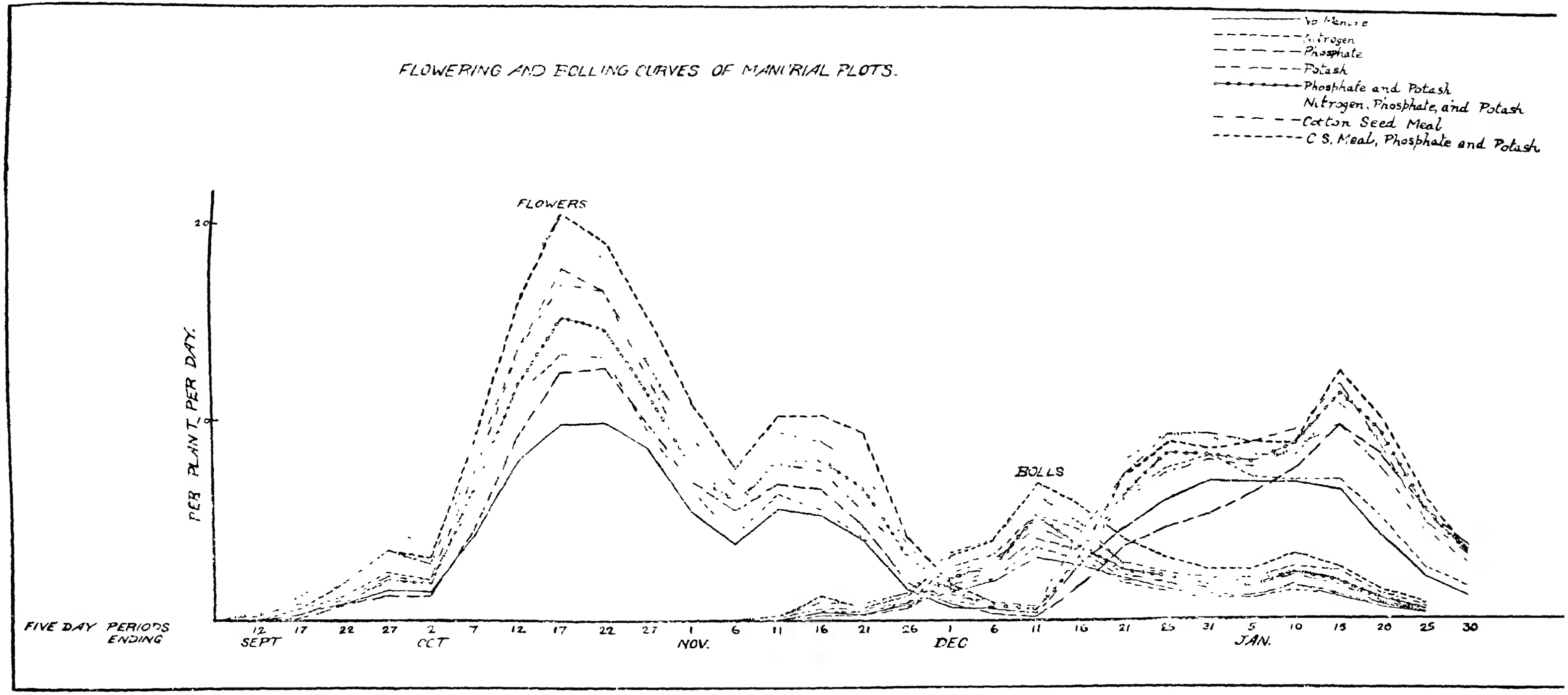
PLATE I.


FLOWERING AND BOLLING CURVES OF MANURIAL PLOTS.
No Manure
Nitrogen
Phosphate
Potash
Phosphate and Potash
Nitrogen, Phosphate, and Potash
Cotton Seed Meal
C S. Meal, Phosphate and Potash
FLOWERS
BOLLS
PER PLANT, PER DAY.
20
10
FIVE DAY PERIODS ENDING
12
SEPT
17
22
27
2
OCT
7
12
17
22
27
1
NOV.
6
11
16
21
26
1
DEC
6
11
16
21
25
31
5
JAN.
10
15
20
25
30

SEA ISLAND B.S.

PLATE 2.

CROP RECORD I.

NUMBER OF FRUITING BRANCH.	1	2	3	4	5	6	7	8	9	10	11
9	B. 10.10 O. 30.11	B. 10.10 D. 26.10	B.S. through E.B.D.	F. 20.10 D. 27.10 I.B.D.	F. 26.10 D. 30.10	F. 3.11 D. 5.11	B.S. 14.11	B.S. 15.11	F. 18.11	B.S. 15.12	Ab.
8	B. 10.10 E.B.D. P.	B. 10.10 P. 27.11	F. 11.10 P. 27.11	F. 18.10 D. 21.10	F. 24.10 D. 28.10	F. 31.10 D. 5.11	F. 7.11 D. 11.11	B.S. 27.10	Ab.		
7	D.	D.	F. 10.10 D. 13.10	F. 16.10 D. 1.11 I.B.D. Ax. F.28.10 D. 30.10	F. 22.10 $O\frac{1}{3}$ 11.12	F. 28.10 D. 1.11	F. 4.11 D. 7.11	F. 12.11 D. 18.11	B.S. 15.11	Ab.	
6	B. 10.10 E.B.D. $O\frac{1}{3}$ 11.11	B. 10.10 D. 12.10	B. 10.10 E.B.D. P. 27.11	F. 14.10 E.B.D. P. 27.11	F. 20.10 D. 9.11	F. 26.10 D. 30.10	B.S. 11.10	B.S. 27.10	Ab.		
5	B. 10.10 P. D. 33.11	B. 10.10 O. 27.11	B. 10.10 E.B.D. $O\frac{2}{3}$ 1.12	F. 12.10 $O\frac{1}{3}$ 6.12	F. 18.10 $O\frac{2}{3}$ 11.12	F. 25.10 D. 27.10	B.S. 24.10	B.S.	B.S. 15.11	Ab.	
4	B. 10.10 D. 15.11	D.	B. 10.10 D. 15.10	F. 12.10 D. 15.10	F. 17.10 Rotted through Phytophthora	F. 21.10 E.B.D. slight D. 1.11	B.S. 16.10	B.S. 18.10	B.S. 15.11	Ab.	
3	B. 10.10 O. 14.11	D.	D.	F. 18.10 D. 28.10	F. 24.10 D. 30.10	B.S. 13.10	Ab.				
2	B. 10.10 O. 14.11	D.	D.	F. 8.10 D. 12.10	F. 13.10 D. 15.10	F. 19.10 D. 25.10	F. 25.10 D.4.11	F. 31.10 D. 16.11 I.B.D.	B.S. 16.10	B.S. 14.11	Ab.
1	B. 10.10 Rotted by P. D. 11.11	B. 10.10 Rotted by P. D. 11.11	D.	F. 12.10 D. 15.10	F. 16.10 D. 19.10	B.S. 23.10	F. 29.10 D.31.10	B.S. 15.10	Ab.		

NUMBER OF NODE ON FRUITING BRANCH.

NUMBER OF FRUITING BRANCH.

	1	2	3	4	5	6	7	8	9	10	11
19	F. 29.10 D. 1.11	B.S. 31.10	D.	B.S. 14.11	B.S. 15.11	B.S. 18.11	F. 18.12 D. 2.12 E.B.D.	Ab.			
18	F. 26.10 D. 30.10	B.S. 28.10	B.S. 20.10	B.S.	B.S. 11.11	B.S. 15.11	B.S. 15.11 / Ax F. 15.12 D. 23.12	B.S. 15.11	F. 16.12	B.S. 13.12	Ab.
17	F. 23.10 D. 28.10	B.S.	B.S.	B.S.	B.S.	B.S. 15.11	Ab.				
16	F. 20.10 D. 9.11 E. B.D.	F. 25.10 D. 27.10	D.	F. 7.11 D. 10.11	F. 14.11 O. 4.1	B.S. 18.11	B.S. 15.11	F. 14.12 D. 30.12 I.B.D.	Ab.		
15	F. 18.10 E.B.D. O. 8.12	F. 23.10 D. 27.11 I. B.D.	B.S. through E.B.D.	B.S.	F. 9.11 D. 11.11	F. 16.11 O. 1.1	B.S. 11.11	B.S. 14.11	B.S. 11.12	Ab.	
14	F. 15.10 D. 20.10	F. 20.10 O. 11.12	F. 26.10 O. 11.12	F. 1.11 D. 7.11	F. 10.11 D. 13.11	B.S. 27.10	Ab.				
13	F. 13.10 D. 21.10	F. 17.10 D. 25.10	F. 22.10 D. 30.10	F. 28.10 rotted E.B.D.	B.S.	B.S. 17.10	Accidentally broken				
12	F. 10.10 D. 11.10	F. 15.10 O. 4.12 / F. 15.10 O. 5.12	F. 20.10 / O. 11.12	D.	D.	D.	B.S. 14.11	B.S. 11.11	B.S. 15.11	Ab.	
11	B. 10.10 / O. 27.11	F. 13.10 D. 11.11 / F. 13.10 O. 6.12	F. 18.10 / O. 11.12	F. 21.10 D. 27.10	F. 31.10 D. 5.11	B.S. 27.10	Ab.				
10	D.	F. 11.10 D. 15.10	F. 16.10 / O. 6.12	F. 22.10 O. 11.12 / F. 1.11 O. 19.12	F. 28.10 D. 3.11 / F. 4.11 D. 5.11	F. 1.11 / D. 6.11	Ab.				

NUMBER OF NODE ON FRUITING BRANCH.

NUMBER OF FRUITING BRANCH.	1	2	3	4	5	6	7	8	9	10	11
37	B.S. 12.12										
36	B.S. 8.12	Ab.									
35	F. 26.12 D. 1.1	B.S. 12.12	B.S. 26.12	Ab.							
34	F. 22.12	F. 29.12	Ab.								
33	F. 19.12	F. 26.12 D. 29.12	B.S. 12.12	Ab.							
32	F. 15.12	F. 21.12	F. 29.12 D. 2.1	B.S. 12.12	Ab.						
31	F. 12.12	F. 18.12	F. 26.12 D. 5.1	B.S. 6.12	Ab.						
30	B.S. 18.11	F. 15.12	F. 22.12	Ab.							
29	B.S. 18.11	F. 10.12 D. 23.12	F. 16.12	F. 21.12	F. 31.12 D. 5.1	B.S. 3.1	B.S. 2.1	Ab.			
28	B.S. 18.11	B.S. 18.11	F. 16.12	Ab.							
27	B.S. 18.11	B.S. 18.11	B.S. 18.11	B.S. 11.12	B.S. 2.1	Ab.					
26	B.S.	B.S. 11.11	B.S. 14.11	F. 15.12	Broken						
25	F. 19.11 O. 9.1	B.S. 11.11	B.S. 18.11	F. 13.12	F. 21.12 D. 3.1	Ab.					
24	F. 16.11 P. 12.12	B.S. 11.11	B.S. 11.11	B.S. 18.11	F. 13.12 D. 1.1 E.B.D.	F. 20.12 D. 27.12 I.B.D.	F. 29.12 D. 3.1	B.S. 13.12	Ab.		
23	F. 13.11 D. 17.11	F. 18.11 D. 15.12 E.B.D.	B.S. 18.11	B.S. 18.11	B.S. 18.11	F. 22.12	B.S. 27.12	Ab.			
22	F. 9.11 D. 13.11	F. 15.11 O. 7.1	B.S. 15.11	B.S. 15.11	B.S. 18.11	B.S. 26.11	Ab.				
21	B.S. 31.10	F. 10.11 D. 13.11	F. 16.11 D. 29.11 E.B.D.	B.S. 11.11	F. 30.11 O. 19.1	B.S. 18.11	B.S. 25.11	F. 16.12 D. 4.1	Ab.		
20	D. through E.B.D.	F. 8.11 D. 12.11	F. 14.11 D. 25.11 I.B.D.	B.S. 11.11	B.S. 15.11	F. 16.12 D. 12.1 I.B.D.	F. 26.12 D. 2.1 E.B.D.	Ab.			

NUMBER OF NODE ON FRUITING BRANCH.

MONOPODIAL BRANCH A.

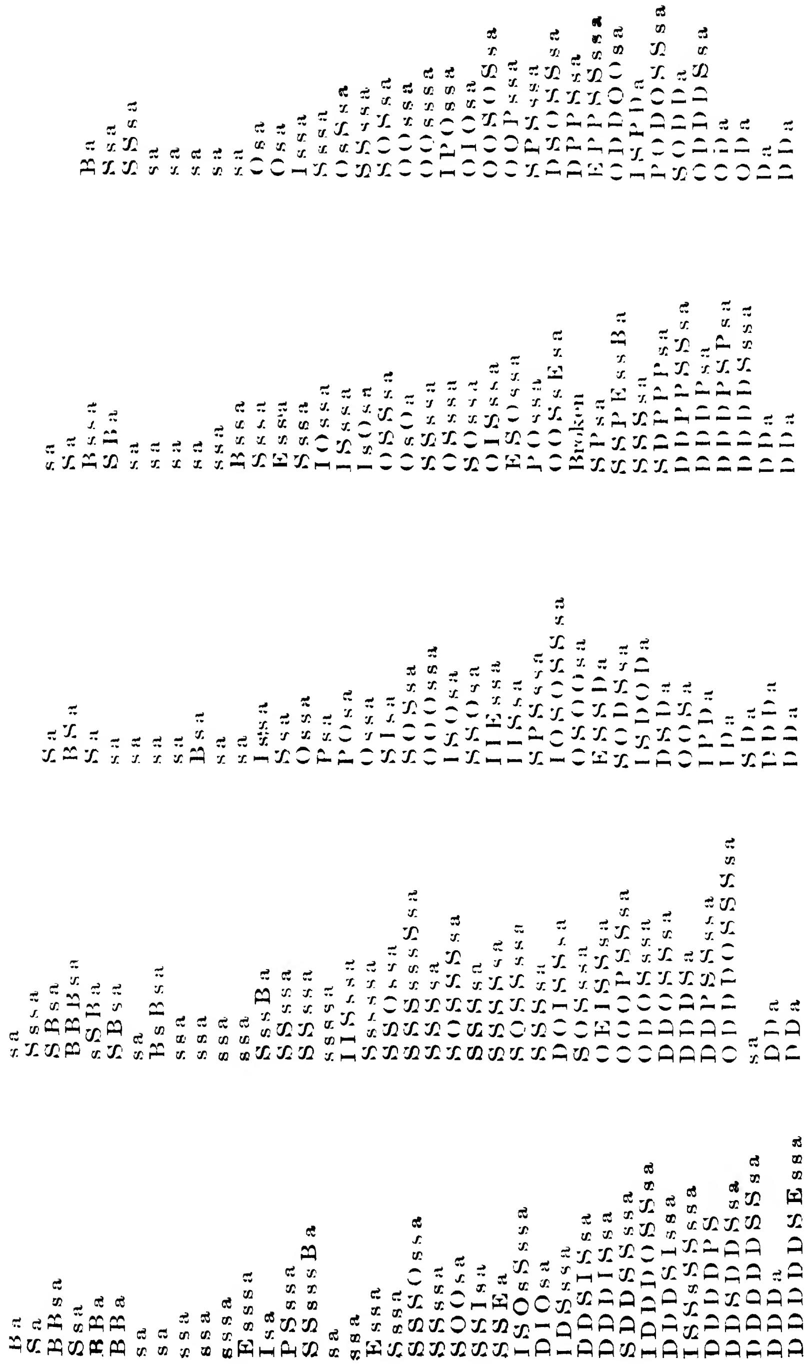
NO. OF FRUITING BRANCH.

	1	2	3	4	5
A. 15	B.S. 1.1.17	Ab.			
A. 14	B.S.	F. 29.12	Ab.		
A. 13	F. 17.12	B.S.	Ab.		
A. 12	F. 13.12	F. 19.12 D.1.1 17 I.B.D.	Ab.		
A. 11	F. 10.12	F. 17.12	Ab.		
A. 10	D.	F. 15.12 D. 18.12	B.S.	Ab.	
A. 9	F. 2.12 O $\frac{2}{3}$. 22.1	F. 11.12 D. 30.12 I.B.D.	F. 18.12	B.S. 1.1	Ab.
A. 8	B.S. 30.11	Ab.			
A. 7	F. 24.11 O. 16.1	B.S.	Ab.		
A. 6	B.S.	B.S.	F. 6.12 D. 23 12 E.B.D.	Ab.	
A. 5	B. 25.11 O. 10.1	B.S. 30.11	Ab.		
A. 4	B.S.	B.S.	Ab.		
A. 3	B. 25.11 D. 12.12 I.B.D.	B.S. 28.11	Ab.		
A. 2	B.S.	B.S.	B.S.	Ab.	
A. 1	B.S. 25.11	B.S.	Ab.		

NUMBER OF NODE ON FRUITING BRANCH.

PLATE 3.

PLANT DIAGRAMS.



FIVE PLANTS FROM MANURIAL PLOTS.

PLATE 4.

PLANT DIAGRAMS.

```
B
s a
s a
s a
s a
s a
s a
S s s a
I s a
O S s a
O S s a
O S S s a
S D S I s a
O O S S s a
S S S S s s B a
O S O S s a
O O S S S s a
I S S S O s s a
P S S S O I s s a
O O S S O s O s a
D S S S O S s s a
D O I O S O D a
D S S S S S S s s a
D O O S S S O S s a
I D O D O S O S s a
D D D O O S S O S a
D D E D O S S S a
D D I O S S D a
```

UPLAND 1.

```
s a
s a
s a
S a
S a
S s a
I S a
s S s a
s S s a
S s S S a
O s S s s a
O S s S a
S O s S S a
S O D S S a
I O S S S s a
O S O S S S s a
S S S O S S s a
O S S S S s S s a
S S S S O O s a
O O S S S S O S a
D S S S P O S s a
S D S S S S S s a
D S S S S S° S O S s a
D S I I O O O a
D S S S S S O S s a
D D O I O S S D s a
O D D D O S S S D s a
S D D S S S S O S s a
S D D O O S D a
```

UPLAND 2.

```
s

s
s
s
s a
s a
s a
O s a
O s a
S O s a
O O s a
S O S s a
S O S s a
O S O s a
O S O S s a
O S S O s a
O S S s a
D O S S s a
O a
```

UPLAND 3.

```
s

s
s a
s a
s s a
S s a
O S s a
S O S s a
O O O s s a
S S O s a
O S O S s a
O O S S s a
D s s S S O s s a
O O S S s s a
O O S S S s a
O O O S S S s a
D D O S s a
```

UPLAND 4.

PLATE 5.

PLANT DIAGRAMS.

KIDNEY.

s
B a
B a
B a
s a
s a
I s a
I s s a
O s a
O I s B
S O a
O O s a
S S s s a
O Broken
O S s I a
S O s a
O O s s a
S S O s a
O O O a
O S s O s a
S O s s s s a
D O s s s s a
D O S s S a

CAUTO × UPLAND (1).

s
s
B B a
B a
s B a
s a
I B B a
S s B s a
S s a
O s s B S a
I s s B a
O I s B S a
O O S s S S a
O O O s I a
O S O s s I B S a
I O S I s S s a
O O O O s S a
S O s O S S I a
S O O S s a
O S O O O S s a
O O O O s a
O S S S O s s O B s a
S S O O O O s a
O O S O O S s a
I S S O a
O O O S S s s a
O O O S O S s a
D O D a

CAUTO × UPLAND (2).

s a
B s a
s a
s a
B B B a
B s a
s a
s a
s s B B B a
S s a
O s I a
S S s B B a
O s s B a
O S S s B s a
O O s s a
S O s s s a
S O O S s B a
I O S s a
S O O O S S a
E S S a
O S O s s a
O O S P S s a
O S S S s a
E O S O S s a
S O O S O s a
O S S P s s a
E O S S s s a
O O O S S s a

CAUTO × UPLAND (3).

s a
B B B a
B B B a
B B S a
s a
s a
s a
s s B a
s s a
S s B B S a
I s s a
S I s s B s a
O O s s a
S O O s s a
O S O s s a
O O I s s a
S O S I s B B s a
S O s I s a
S S I O s s s a
S S O Broken
S S S I S s B
S S O D s s a
S S S O I S s s s a
S S S I O s a
S S S S s a
D S S S S S S s B s a
O S D S S I s a
D I S S S O s s a
O D S I S O s s I a
D O S S S O I a
D D O S S s P O I S s I S S a
D D O Broken
D D O O S S S O s a
Broken
O D D D Broken
D D D D Broken
O D D I O O S S O a
D D D O I O S O s a

PLATE 6.

PLANT DIAGRAMS.

S s a
S a
S a
S S a
S S S a
B S S a
B B S a
B B S S s a
B B S B a
B B S S s a
I B S S S s a
I B B B S a
I B S S S a
s I I S S S S a
s I O S a
s s I S S a
s s I I B S a
s s s O B S a
s s s I S S s a
s s s O S s a
s s s s s a
s s s s I B S S a
s s s s a

I. 11. 1

s a
S S a
S S s a
S S s a
B S s a
B S S s a
B B B B a
B S S S a
I B B B S a
I B B B S a
O I B B S a
s I S S S a
s I B B S a
I s I B S a
s s I B B a
O s s I B s s a
s s s I I S S s a
s s s s O B a
s s s s s B B S a
I s s s I a
O s s s I B S a
S s s s O B s s a
S s s a
s s s s a
s a
s s a

I. 11. 2.

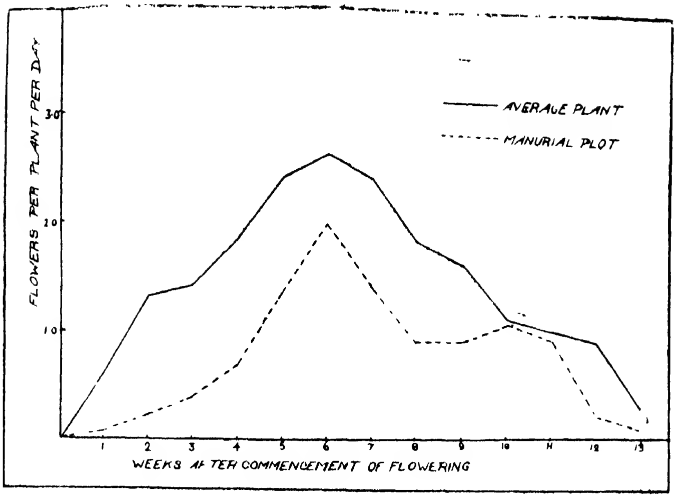
B B s s
B B B s
S S S a
S S S S
S S B B s a
S S S B s a
B S S B B a
B S S B s a
B B S S S s a
B B S S S s a
B B B S B s a
B B B S S S s a
B B B B B B s a
s B B S S s a
I s a

37.

S S B
S S S B
B S B B
S S s a
B B S S B
B S S B
B B S S B a
B B S S B
B B B S B s
I B S S S B B
I S B S S B
s S s S S B B
I I S S a
I I S s a
O s a
O s a
s s a

38.

PLATE 7.



Flowering curve of average plant compared with flowering curve of a single plot in manurial series.

PLATE 8.

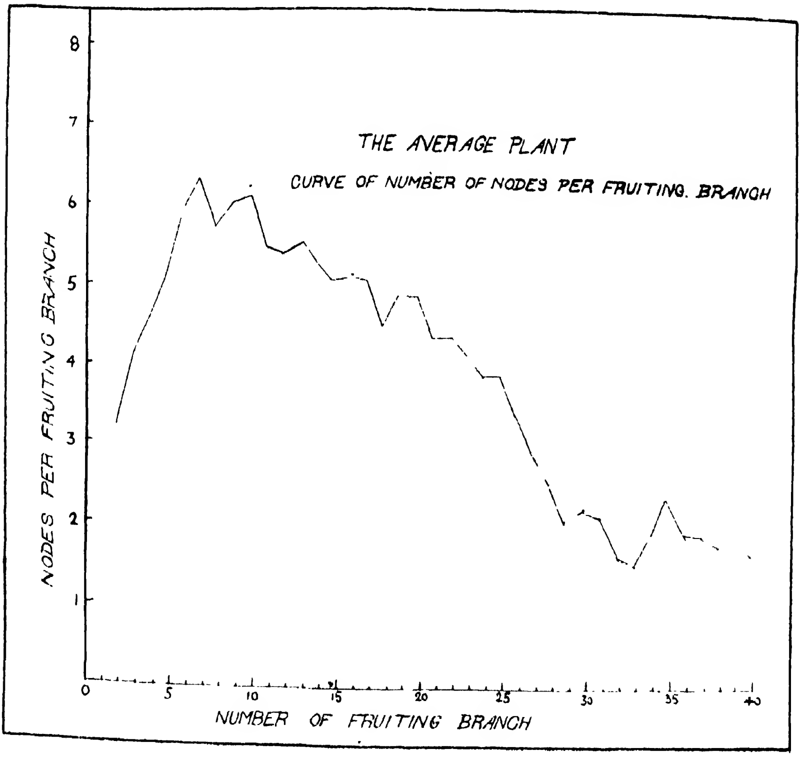


PLATE 9.

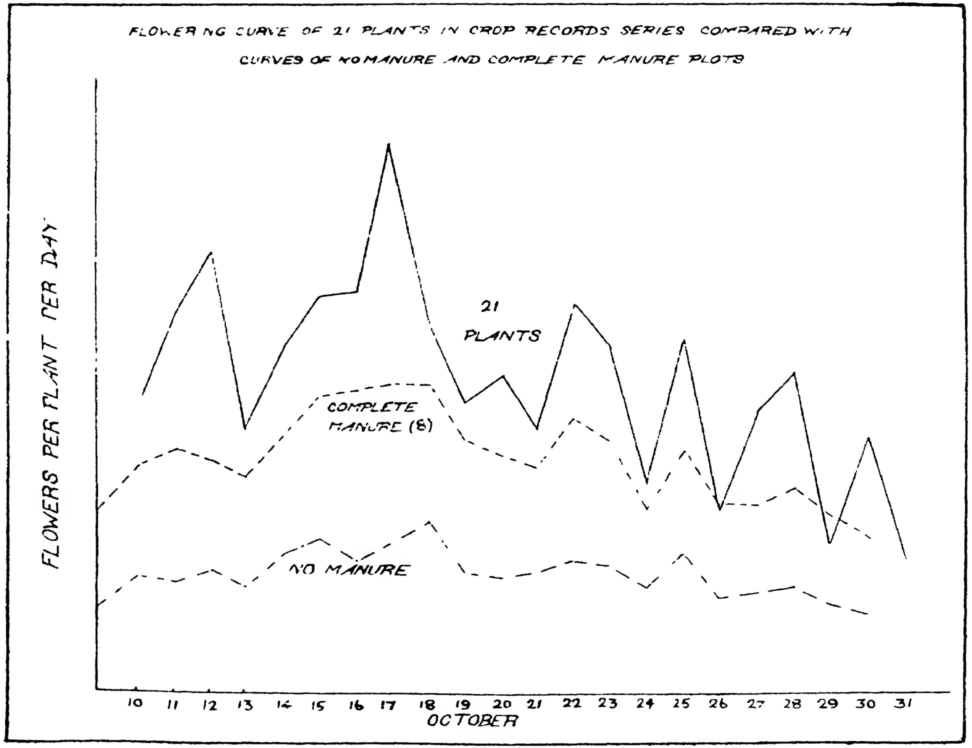
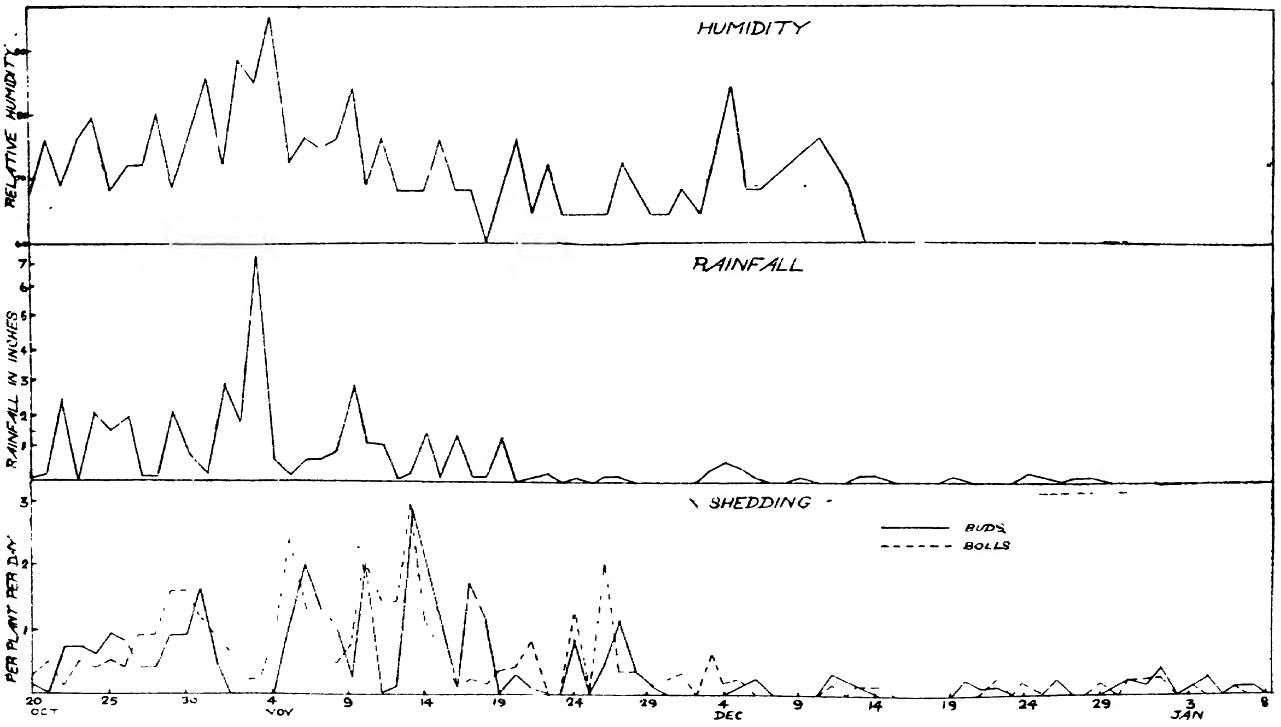

FLOWERING CURVE OF 21 PLANTS IN CROP RECORDS SERIES COMPARED WITH
CURVES OF NO MANURE AND COMPLETE MANURE PLOTS
FLOWERS PER PLANT PER DAY
21
PLANTS
COMPLETE
MANURE (8)
NO MANURE
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
OCTOBER

Plate 10.

GRAPHS SHOWING RELATION BETWEEN SHEDDING, RAINFALL AND RELATIVE HUMIDITY



INTERNAL DISEASE OF COTTON BOLLS IN THE WEST INDIES.

BY WM. NOWELL, D.I.C.,

Mycologist on the Staff of the Imperial Department of Agriculture for the West Indies.

This paper deals with the facts ascertained and the conclusions reached in the study, as yet incomplete, of an affection of cotton bolls in the West Indies, characterized by the progressive staining and rotting of the lint in green unopened bolls of healthy external appearance.

Such staining is shown to be due to the infection of the contents of the boll with certain specific fungi,* previously described in this Journal[14], or with bacteria as yet undefined; which organisms gain access to the interior of the boll by means of the punctures made by bugs, mainly *Dysdercus* spp. (cotton stainers) and *Nezara viridula* (green bug).

In bolls which are approaching to full size, and in which the lint is well developed, the result of an infection is the production of a stained patch due to the growth of the invading fungus or bacterium on the lint. According to circumstances this may be small, or may, alone or with other infections, spoil the contents of the whole lock. The effect on younger bolls is more uniformly severe, owing to the more susceptible condition of the boll contents, and the longer time afforded for the growth of the invading organism. Many such bolls are shed before maturity, and in the remainder the contents of the infected locks are more or less completely rotted.

The prevalence of the affection is much greater in some islands than in others, and in some seasons than in others. Heavy losses from the disease are experienced only in the second half of the picking season. In the years and situations most marked by its prevalence the losses in the first picking of May-planted cotton (September-October-November) are commonly negligible, and have not been found to exceed 20 per cent. in the local outbreaks which have occurred, but during the second picking (November-December-January) they rise very rapidly and in the last-mentioned month may be close upon 100 per cent. The yield of early planted cotton is thus not seriously affected, but that of late cotton is, on occasion, almost totally destroyed.

*Four species have been found, referred to for the present by the letters A-D. All bear elongated spores in sporangia which originate as expansions of simple hyphae. In species A the spores show no orderly arrangement. In Species B they occur in two conical bundles interlocking at the base; this form appears to correspond with *Eremothecium cymbalariae*, Borzi. In Species C and D the spores typically lie in two equal groups end to end, some distance apart but connected by the whiplike appendages of the spores. The thallus of Species C is typically hyphal; that of D is typically yeast-like, but assumes the hyphal form under some circumstances. Species closely resembling D have been described as forming the genus Nematospora. Both the genera named occur so far as is known only in fruits.

I. REVIEW OF LITERATURE.

Damage to Cotton by Bugs.

The statements of entomologists with regard to the manner in which bugs of the genera Dysdercus and Oxycarenus earn their popular name of cotton stainers are marked by a spirit of hesitation and surmise.

Mr. H. A. Ballou [2] and Dr. A. W. Morrill [12] have each collected references to this question. Ballou writes:—

In the West Indies, there seems to be a considerable difference of opinion as to the amount of damage caused by cotton stainers. Planters believe that these insects injure the young bolls by puncturing them and sucking the juice, and that they injure the fibre by staining it; but they do not seem to have estimated the loss from this cause, either in the amount of the crop or in the reduced value of the stained cotton. It cannot, however, be doubted that the presence of large numbers of these insects in cotton fields causes a considerable decrease in the amount and value of the crop.

The same author points out the need for investigation of the whole question of cotton stainer injury. His own conclusion is, that, in addition to the damage directly due to the drain upon the juices of the tender parts of the plant, the young insects may cause staining by feeding in newly opened bolls. He mentions the possibility of their being caught in the gins and crushed, thus imparting a stain to the lint.

Ballou quotes, among others, the following authors: (a) Schwartz, to the effect that cotton stainers in the Bahamas regularly destroy the entire summer (January) crop, and half or more of the second crop; (b) Glover, that the principal injury the cotton stainer does is by sucking the juice of the seed and boll and then voiding an excrementitious liquid which stains the fibre yellow or reddish; (c) Howard, who states that in Cuba, although enormous numbers of the species *D. andreae* occurred on the young bolls in January or February before they opened, they had no effect on the plant except the dwarfing of the bolls Towards the end of March, however, when the picking had been nearly finished, the stainers attacked the fibre remaining in the field, and stained it badly.

Morrill refers (a) to Glover as having, in 1855, indicated plant bugs as possible producers of rot in cotton bolls, (b) to Mally as recording that certain bugs puncture bolls causing them either to drop or, alternatively, to have a tuft of stained lint in the section punctured, and (c) to similar observations by Sanderson.

Morrill is able to state positively that the popular idea that staining is due to excrement is unfounded in Mexico, and he is disposed to be sceptical of all similar statements. Eight stainers (Dysdercus) kept by him for ten days in a cage over a layer of seed-cotton, and fed on a green boll and a piece of orange rind, caused no staining of the lint. He directs special attention to the observation of a Sea Island grower in Florida who wrote to Glover:—

The pod or boll is perforated by the bug. Whether the staining matter is imparted to the fiber of the cotton during the perforation directly, or by a slow process diffusing itself with the sap abounding at the time is no

ascertained. I am of the latter opinion, from the fact that almost the entire product of the boll is discoloured when it opens, which does not seem at all to cause a premature development.

Morrill has made the most complete study yet published of the injuries arising from plant bug attack on cotton bolls. The observations were made for the most part in connexion with the conchuela (*Pentatoma ligata*, Say) but it was found that the same effects were produced by other bugs upon which studies were made.

He gives a detailed description of the effects of punctures, (quoted in a later section of this paper) with which the observations made by the present writer, in connexion with cotton stainers and green bug, exactly correspond.

He mentions cases of damage in the United States, mostly attributable to Pentatomid bugs, extending to 4 or 5 per cent. over a large area, and a particular case where of forty three green bolls picked at random, 58 per cent. were damaged, 50 per cent. being ruined, and the others badly stained.

An examination of twenty-five bolls showed an average number of 8·9 punctures in destroyed locks. 5·3 in slightly injured locks, and 1·8 in uninjured locks One boll had fifty-five punctures, with the lint only slightly stained. From the figures given and from the mention of heavy staining and decay of lint, it seems probable, in the light of West Indian experience. that organic infections were involved. With this aspect of the subject the writer does not deal, beyond indicating the transmission of boll diseases by bugs as a promising field for research.

Messrs. P. L. Guppy and T. Thornton,[8] writing of the cotton stainer in Trinidad and Tobago, say:—

> The damage is done before the bolls open by the insects piercing the walls in order to obtain the juices, and the cell sap exudes through the punctures thus made on to the cotton lint which is being formed inside the boll.

The damage done by *Dysdercus cingulatus*, Fabr., in India, is discussed by Professor H. Maxwell-Lefroy.[10] The main attack is on the green boll, and the result of the extraction of sap is shedding or the production of small bolls containing bad fibre, which open prematurely. The deposition of excrement in open bolls and the crushing of nymphs are referred to, but the statement is made that the normal damage to cotton in India is not by staining.

The cotton stainer in Egypt is *Oxycarenus hyalipennis*, Costa, which becomes extremely plentiful towards the end of the picking season. Mr. F. C. Willcocks[18] states that the injury effected is not very apparent and is difficult to define. It probably consists of shedding, 'light seed,' and weakening of fibre, induced by the sucking of the juices of bolls and seeds; matting of fibre, and dirtying of the fibre by means of cast skins and excrement. The influence of excrement and gin-crushed stainers is regarded as unimportant.

Dr. W. L. Balls[3] has commented on the damage done to cotton seed in Egypt by stainers. In circumstances which permitted of accurate determination it was found that the percentage of seed which failed to germinate was proportional to the time of its exposure to the bugs and the numbers in which they were present. The proportion reached 98 per cent. in

extreme cases. The failure to germinate was traced to a condition of the radicle marked by brown discoloration. The cells in this organ were found to be unhealthy or dead. No infection could be detected. Tests which were made showed clearly that the saliva of the bug is in some way poisonous, and continues to destroy the cells in contact with it for some time after the proboscis of the bug is withdrawn. In this connexion it may be noted that Mr. D. G. Tower [17] has described an elaborate pumping mechanism existing in the squash bug (*Anasa tristis*, Deg.) by means of which a charge of saliva is forced down the salivary canal which exists in the setae and into the plant tissues.

The effect of poisoning the protoplasm will be to facilitate the removal, with the cell sap, of the dissolved substances, notably sugars, which otherwise would not pass the protoplasmic membrane.

Association of Insects with Boll Rots.

Conclusions approaching those of the present writer were reached many years ago in an investigation, which appears to have been started by Mr. J. M. Stedman and continued by Mr. C. F. Baker and Mr. F. S. Earle, of a cotton boll rot in Alabama. Unfortunately the original papers are not accessible to the writer, and only references in general text-books are available [1,6].

Stedman, in 1894, described a bacterium (*Bacillus gossypinus*) found in closed bolls, producing a rot which is not apparent from the outside. If the rot begins some time before maturity is reached the entire boll will rot and not open; but it may begin so late that only a few seeds and a small portion of the lint are affected, while the carpels separate and the lint may be exposed and gathered. The organism will not induce pathological conditions in any other part of the plant than the boll. The disease is most severe in wet weather.

Baker enlarged the list of organisms found in infected bolls to include three species of *Bacillus*, *Colletotrichum gossypii*, and species of *Fusarium*, *Alternaria* and *Rhinotrichum*, of which organisms one or more of the bacteria were probably primary. He reached the conclusion that access to the boll contents was obtained through the punctures of small leaf-hoppers (*Tettigoniidae* of the genus *Diedrocephala*).

More recently (1912) Mr. C. W. Edgerton, [7] writing of cotton boll rots, refers to three species of bacteria common in rotting cotton bolls in Louisiana. One, and by far the most important, is *Bacterium malvacearum*, Smith, which is a true parasite attacking uninjured bolls. (Its effects as such are familiar in the West Indies.) The other two develop in injured bolls or bolls already affected by some other organism. Bolls were artificially inoculated with each of the three, using a fine pointed needle. The first-mentioned in nearly all cases produced the typical water-soaked spots around the points of inoculation, while in no case did either of the others have this effect. There was but very little difference apparent in the rotting ability of the three organisms. All of them seem to be able to rot and

discolour the tissue in the punctured locks, while none of them is able to pass from one lock to another without an injury. It is mentioned also, that bolls that are well advanced do not have the interior rotted by any of these bacteria. After the lint fibres have begun to harden the bacteria will sometimes stain them slightly yellowish at the point of infection, but there is no rot.

The greater damage done by *Bacterium malvacearum* as compared to the other two forms is due to its ability to attack the uninjured epidermis of the boll and gain entrance to the interior. The other forms are unable to do this, being able to gain entrance only through an injury. A significant point is that the two unnamed bacteria were found to be very common on all parts of the cotton plant.

The function of bug punctures in affording points of entrance to the bacteria, including *B. malvacearum* is briefly mentioned.

West Indian references to internal boll disease are reviewed in their due sequence in the next section.

II. THE INVESTIGATION OF THE DISEASE IN THE WEST INDIES.

The first report of the affection came from Montserrat. The revival of the cotton industry in the West Indies began on a commercial scale in the season 1902-3, in which period about 12 acres were under the crop in Montserrat. In the following season this was increased to 700 acres, and in December 1903, affected bolls were received at this Office from Mr. Conrad Watson. In a letter to Sir Daniel Morris, Commissioner of Agriculture, dated January 26, 1904, Mr. Watson wrote :—

> On the 2nd December 1903 I forwarded to you some specimens of bolls of cotton which appeared to rot before the bolls opened.
>
> Since that date the disease has spread, and at present, the whole of the windward portion of the island under cotton, about 400 acres, is infested.
>
> Going through fields and picking fine looking bolls from most promising looking trees I only found 10 per cent. of good bolls.
>
> At Bethel and Whites Estates from 260 acres of cotton I reaped about 1,200 tb. of seed-cotton, the fields were covered with bolls and I expected a very heavy, if late crop, but the bolls are dropping, and those left on the trees seem to be rotten.

The specimens were examined by Mr. L. Lewton-Brain, then Mycologist to the Department, who reported the presence of Cercospora blotching and a small amount of anthracnose, but did not suggest these as the cause of the trouble. He recommended experiments with Bordeaux mixture.

In March of the same year Sir Daniel Morris wrote to the Commissioner of Montserrat as follows :—

> With reference to the black rot in cotton, now I have received returns of the rainfall I have little doubt that this is not an organic disease but the result of a humid condition of the soil and atmosphere.

In December 1904, two reports as to the disease in Montserrat were made by Mr. A. J. Jordan, and one by Mr. W. H. Patterson, Curators of the Botanic Stations at Montserrat and Antigua, respectively. Jordan's first report contains no information on the subject ; Patterson's associates a mis-shaping and hardening

of the bolls with the disease, gives evidence of its rapid development, and shows that rotation of crops and manuring have apparently no effect upon its incidence. Jordan's second report, made in connexion with Patterson's visit, describes the affected bolls as 'oval-cuspidate' in all but one instance, but records the finding of healthy bolls also of this shape. The sprouting of the seeds in some of the rotted bolls is mentioned. In January 1905, Patterson reported the occurrence of the same disease in Antigua.

In February 1905, Lewton-Brain[11] made an investigation of the affection in Antigua and Montserrat. He records the existence of a distinct disease of the bolls, differing entirely from anthracnose and 'physiological drying up,' though sometimes confused with these. After alluding to the deformation of the bolls and their hardness (characters which are not particularly evident in the material more recently examined), he describes the occurrence of discoloured rotting lint in bolls of healthy external appearance, ending in a condition in which the enlarged partially germinated seeds are separated only by a thin film of decayed lint. Such bolls usually drop about the time they should be opening, and fields were seen which had lost every boll in this way. Sometimes the bolls dry up on the plant and open slightly, when they are distinguishable by the appearance of the lint. The disease could not be ascribed to climatic conditions, since it had occurred in very dry and very wet seasons; nor could the condition of the soil be responsible, since it occurred on both limestone and clay, on poor and on rich land. He was unable to connect the disease with any insect attack, or with any of the known diseases of cotton. A plant might have one or two bolls affected while the remainder continued healthy, and plants which had lost every boll might afterwards bear sound bolls in the second crop. No corresponding affection of stems or leaves could be found. He reported the presence in affected bolls of a rod-shaped bacillus which he regarded as the probable primary cause of the disease, suggesting the possibility of flower infection by the agency of wind or insects. He outlined a series of field experiments to ascertain the stage at which infection takes place, but there is no record of these having been carried out.

From the time of Lewton-Brain's report the subject does not appear to have been brought to the notice of the Imperial Department until 1911.

A report by Mr. A. W. Bartlett, [4] Government Botanist of British Guiana, dated January 1907, contains a detailed account of an affection of cotton bolls in that Colony, which is clearly identical with the one under discussion. In addition to his description of its general features, Bartlett reports that when any affected boll was cut open and a little of the yellow lint teased out and examined, it was found to be infested by the hyphae of a fungus. This organism produces spindle-shaped spores in large club-shaped sporangia, which are borne terminally on short lateral branches or sometimes in the middle of the hyphae. The base and the apex of the sporangium are similar in form and size, and the latter is usually produced to form a short neck with a rounded end. The spores measure 17·20 × 2 microns, the

sporangia 105-135 × 9-14. This is quite clearly the 'Species A' of the present author, and it appears probable from a reference to spores adhering in groups and bearing flagellae (which he mistook for very fine germ tubes) that Bartlett also encountered one of the species of *Nematospora*. The results of his attempts to cultivate the fungus appear to have been confused by admixture with secondary species.

Bartlett notes the close resemblance of his boll rot to the Montserrat 'black boll', as described by Lewton-Brain, but rejects the idea of their identity owing to the difference in the invading organism, he having been unable to find bacteria, reported as constantly present by Lewton-Brain, while never failing to find the mycelium and spores of the fungus.

Bartlett did not suggest any connexion between insects and the disease. His report does not seem to have received the attention it merited, and was only turned up by accident by the present writer at an advanced stage of these investigations.

In March 1911, Mr. W. Robson, Curator from 1905 of the Botanic Station at Montserrat, in the course of correspondence concerning the incidence of bacterial blight due to *Bacterium malvacearum* in that island, submitted specimens of what appeared to him to be a distinct boll affection. Mr. F. W. South, Mycologist to this Department, examined these and noticed in the majority of the bolls the association of discoloured lint with proliferations of the inside tissues of the walls, bacteria being present in some of the more decayed specimens. He regarded the existence of the proliferations as suggestive of damage by sucking insects. In the same month Robson called attention to the occurrence on two estates of large numbers of internally discoloured bolls. In response to a query by South he expressed the opinion that cotton stainers were not present on these fields at the time of the observations. The damage might have been caused by other insects but he did not recall seeing any to which it might be attributed.

Further reference was made to the affection in the Report of the Montserrat Botanic Station for 1911-12, and in the same report the cotton stainer was said to be increasing in importance as a cotton pest, so that many planters had found it necessary to adopt means of control.

In December 1913, Robson's attention was again called to the subject by the presence of discoloured lint in the second crop of that season. He recorded the occurrence of cotton stainers, but regarded the apparent disproportion between their observed numbers and the amount of the injury as telling against the suggested connexion. Material collected at this time was examined by the present writer, who found the general appearance of the affected bolls to coincide in all particulars, except that of abnormal shape, with the description given by Lewton-Brain. Proliferations, as described by Morrill and mentioned by South, were found to be common in the affected bolls, and it seemed clear in some cases that the rot had commenced from these. Bacteria, as described by Lewton-Brain, were not present, but in all cases hyphae were found growing amongst the lint and in the lumina of the fibres.

Spores of the fungus afterwards differentiated as Species A were present to a greater or lesser extent in all the examples.

In January 1914, Robson confirmed the early account of the rapidity with which the affection developed by finding discoloured bolls to be quite general in fields which three weeks before had been comparatively free. He noted the occurrence of the trouble on plots of hybrid St. Eustatius and on Sakellarides and other Egyptian types. Later he added to this list the Montserrat wild cotton (a form of the perennial *Gossypium barbadense*). He attributes to the effects of the disease the poor germination of seed from the second picking which he had noticed for some years.

Experiment 1.

In May 1914, five experimental plots were started in Montserrat on lines suggested by the present writer to test the assumption that a definite fungus infection was concerned. Plots 1, 2, and 3 of some fifty plants each, were planted in close proximity; two of them with seed from stained bolls, treated with corrosive sublimate solution in one and untreated in the other; and one with seed from Barbados, where the affection was not known to occur.

The method of sampling adopted was to examine on each occasion one fully or nearly fully developed but unopened boll from each plant. Examples of the affected bolls from each plot were forwarded to the writer. The results of the examinations are set out in Table A.

There was no material difference in the results of the three plots above-mentioned. The first crop, picked in September and October, gave a percentage of affected bolls which varied irregularly from 10 to 20 per cent. With the beginning of the 'second picking' on November 11, the number had fallen to zero on each plot and it remained very low throughout the month. In December a rapid and regular rise took place, reaching the neighbourhood of 70 per cent. towards the end of the month, and maintained in the eighties and nineties in the two January pickings which concluded the experiment.

The fourth plot, remote from the above, was planted with Barbados seed on land not recently in cotton. No staining whatever occurred during September, October, and November, but from early December onward the plot shared in the rapid rise which took place at the same time on the previously described plots.

During the course of these experiments Robson became convinced that the cotton stainer bug is the cause, or at least a necessary agent, of the affection.

He gave as his reasons for this view: (a) the absence of the affection in situations where cotton stainers are not found, (b) the high percentage of affected bolls whenever cotton stainers are plentiful, (c) the constant association of proliferations on the inside of the carpels with the staining, and (d) the occurrence, in bolls in which staining is just commencing, of small water-soaked spots, taken as indicating punctures such as would be caused by the setae of the bug.

Table A.

Plot.	1		2		3		4		5		1	2	3	4	5
Date.	Exd.	Disd.	Exd.	Disd.	Exd.	Disd.	Exd.	Disd.	Exd.	Disd.	Per cent. diseased.				
Sept. 12	57	8	60	7	60	9	35	0	39	2	14	11	15	0	5
24	56	6	60	14	60	10	36	0	40	0	10	23	16	0	0
Oct. 12	46	9	50	8	58	8	15	0	25	1	19	16	13	0	4
27	27	2	35	6	46	5	0	0	14	0	7	17	10	0	0
Nov. 11	51	0	58	0	45	0	31	0	30	0	0	0	0	0	0
21	53	1	59	1	58	1	30	0	38	0	2	2	2	0	0
Dec. 1	50	3	59	2	55	2	31	1	40	3	6	2	2	3	7
7	53	10	55	4	56	2	28	6	39	3	19	7	4	21	7
16	54	37	57	22	58	27	25	14	38	5	68	38	46	56	13
23	52	41	56	38	56	28	25	7	39	2	78	67	50	28	5
28	53	36	60	44	59	36	29	15	140	20	68	73	61	51	14
Jan. 4	55	51	58	43	51	43	25	17	85	13	92	74	84	68	15
12	52	48	54	51	59	50	15	11	80	4	92	94	84	73	5

The history of the fifth of the plots above-mentioned is interesting in this connexion. It was planted with Barbados seed on land where cotton grown the previous season had been heavily stained, and the rest of which was now in sugar-cane. During September and October staining was recorded in two out of five examinations, namely 5 per cent. on September 12, 4 per cent. on October 12. Whether bugs were present on these occasions was not recorded. There was no staining during November. On the 27th of that month about 100 stainer bugs were artificially introduced. Affected bolls occurred at each examination during December and January, varying irregularly from 5 to 15 per cent. The bugs did not seem to find the situation congenial and are reported to have all disappeared by the end of December. The significant point is that, while on all the other plots, which remained infested with the insects, the amount of staining reached 40 per cent. by the middle of December and culminated at the last observation in January at 92, 94, 84, and 73, per cent., respectively, the amount on the fifth plot did not go above 15 and ended at 5 per cent.

Examination of the affected bolls from the plots revealed that in a small proportion of cases bacteria were dominant, in the rest fungus hyphae were abundant in the stained lint. The spores seen in the previous year were not found, which may or may not have been due to the poor state of preservation of the material. The identity of the fungus is therefore uncertain.

Experiment 2.

When he began to suspect stainers as the cause of the affection Robson tried to imitate their action by pricking about twenty bolls with a needle. Six days later they were put into spirit and forwarded for examination. It was found that in most cases the appearance was not different from what one would expect from a merely mechanical injury to young seeds. A considerable number of the cells had been killed, and there was a stained spot, apparently free from organisms, on the lint around the wound. In certain cases, however, lint on the seeds adjacent to those actually wounded had become stained, and a rot had set in which involved or tended to involve the whole contents of a loculus. In three cases this rot appeared to be purely bacterial, in three others it was wholly or in part fungoid. No spores were seen in connexion with the latter.

With a view to definite proof of the dependence of the disease on insect punctures the use of bug-proof cages enclosing plants in the field was suggested. In the first instance (Experiment 3) an attempt was made to keep the field free from stainers. This failed, but the results have some significance. In the second, (Experiment 4) the conditions were under control and the results are definite. The slight infection shown in the second trial may have been due to green bug.

Experiment 3.

December 1914. W. Robson.

Single plants in the open field, bearing green bolls, enclosed in a muslin cage with about 100 stainers. Stainers were present in the field.

DEGREE OF INFESTATION WITH I.B.D.

	First trial.			Second trial.		
	Bolls.	Inf.	Per cent.	Bolls.	Inf.	Per cent.
An adjacent plant at the time of enclosure	76	1	1	65	8	12
Enclosed plant at end of one week	81	61	75	86	44	51
An adjacent plant " " " "	88	13	15	77	31	40

Experiment 4.

August-September 1915. W. Robson.

Two muslin cages were placed at the same time around single plants in the field. Into one cage a large number of stainers were introduced. Stainers appeared to be absent from the field, but there were very probably a few green bugs present. Two trials.

DEGREE OF INFESTATION AT END OF EXPERIMENT.

Cage.	Healthy bolls.	Slightly affected.	Severely affected.	Per cent. inf.
1 With stainers ...	26	16	4	13
Without stainers ..	29	none	none	none
2 With stainers ..	6	14	12	81
Without stainers ..	43	1	1	4

Duration of 1st trial ten days, of 2nd trial fifteen days.

The results obtained in similar experiments in St. Vincent after the recognition of the affection in that island, may be given here for comparison. The trials were carried out by Mr. S. C. Harland, Assistant Agricultural Superintendent.

Experiment 5.

January 1916. S. C. Harland.

Six plants from a plot of Sea Island cotton with 98 per cent. diseased bolls had the bolls removed. Three plants were placed under a muslin cage and three were left uncaged. Three weeks later the bolls from each plant were examined.

CAGED PLANTS.

No. of plant.	No. of bolls.	No. of diseased bolls.	Per cent., diseased.	Remarks.
1	15	none	none	One stainer was
2	10	2	20	found under the
3	13	none	none	cage.

UNCAGED PLANTS.

1	10	9	90	
2	14	12	86	
3	9	8	88	

EXPERIMENT 6.

January 1916. S. C. Harland.

A Brazilian cotton plant was selected which was growing in an isolated position. There were no stainers on the plant and an examination of fifteen bolls showed that no internal boll disease was present.

Ten of the remaining bolls were enclosed in muslin bags. In five of the bags a pair of stainers were imprisoned. The bolls were examined ten days later.

BAGGED BOLLS.

Bolls with stainers.	4 showed definite disease. 1 ,, proliferations with doubtful disease.
Bolls without stainers.	All 5 were healthy.

Bolls from the Montserrat and (later) the St. Vincent series of experiments were preserved and forwarded for examination. The fungus previously mentioned (Species A) was found to be generally present, and in addition spores belonging to Species C or D were noticed in many of the bolls.

Unless the effect of stainer injury depended on infection with organisms of limited distribution, it was obvious that the same affection should exist in other stainer-infested islands. Enquiries on this point, made in the early part of 1915, led to its recognition in Tortola and amongst the complex of boll rots induced by the wet climate of St. Vincent. From the latter island a number of full-sized green bolls, of sound appearance, were obtained near the end of the crop season. All had stained lint in one or more locks, and in every case the discoloration appeared to be due to the growth of fungi or bacteria, the former being by far the more common. In the greater number of cases spores were present, often in large numbers, which were identical in appearance with those found in the Montserrat material of 1913-14 (Species A). In a few of the St. Vincent specimens containing hyphae these spores were not found, and in others only bacteria in great abundance were seen.

In the Tortola material was seen for the first time in this connexion the fungus denoted as Species B, which seems identical with *Eremothecium cymbalariae*, Borzi, found in fruits of *Linaria cymbalariae* and of *Cachrys laevigata* in Europe. The same fungus has since been found (1917) in cotton bolls from St. Kitts.

In August 1915 a note appeared in the *Bulletin* of the Jamaica Department of Agriculture to the effect that the Microbiologist (Mr. S. F. Ashby) had traced a cotton boll rot experienced in that island to infection through the punctures of cotton stainers. Copies of reports dated April and May 1915, forwarded later by Mr. Ashby, show that he had then obtained from rotted lint the fungus referred to in this paper as Species A and had recognized the connexion of cotton stainers with the disease.

In January 1916 the writer found bolls showing the disease on a self-sown cotton plant of perennial type growing on the seashore near Bridgetown, Barbados. In these bolls the fungus *Nematospora* sp. (Species D) was invariably and solely present, and pure cultures of it were obtained. Cotton stainers are absent from Barbados, and there is no such return of stained cotton as occurs in the case of the other islands.

On the plant referred to, a few adult green bugs (*Nezara*) were present. When these soon afterwards disappeared the new bolls ceased to become affected, but the disease reappeared as a new brood developed. A period of cessation of growth and defoliation, due to drought, followed and caused the dispersal of the bugs, and abundant new shoots and bolls which appeared later were free from bugs and from disease.

In March 1916 the disease was recognized in St. Kitts in a plot of late cotton at the Experiment Station. Specimens were received in May of the same year from Antigua and its dependency Barbuda. In each case the damage was associated with one or more of the characteristic fungi.

In the early part of the present year (1917) a parcel of bolls received from Montserrat was found to be infested with the previously unrecognized form denoted Species C, which was also found soon afterwards in material from Antigua and Nevis. Species B, previously seen only in bolls from Tortola, was found in material from St. Kitts. The examination of a large amount of material in St. Vincent in November 1916, and of several parcels received from that island during December and January showed Species A and D to be very prevalent, but did not reveal the presence of Species B or C.

The following table shows the distribution of the fungus forms so far as it is at present ascertained. One or more of these species is known to occur in each island, but observations made before they were fully defined are doubtful except where material has been preserved. The bolls examined at any one time have been obtained from narrowly limited districts, so that the evidence has very little negative value.

Table B.

DISTRIBUTION OF THE ASSOCIATED FUNGI.

		A.	B.	C.	D.
(a)	Jamaica	×			×
	Tortola		×		
	St. Kitts		×		
	Nevis			×	
	Antigua...			×	
	Barbuda	?			
	Montserrat	×		×	
	St. Vincent	×			×
	Barbados				×
(b)	British Guiana... ...	×			?

(a) Ashby (b) Bartlett

During the course of the investigations outlined above occasional examples were met with in which the infection of outwardly sound bolls was purely bacterial. Such cases were never very numerous, and were often absent from the bolls examined up to the time of my visit to St. Vincent in November 1916. On this occasion the position found on arrival at the Experiment Station at Kingstown was that in at least 90 per cent. of the large number of bolls examined the infection was bacterial; the remainder being due to Species D. A consignment of bolls from the district near Georgetown, on the Windward Coast, showed infections about evenly divided between bacteria and Species A. The two or three weeks immediately preceding had been marked by extreme and quite unseasonable wetness. This period was succeeded by fine weather, and the proportion of bacterial infections rapidly fell to its previous position, where it remained for the rest of the season. Bolls collected in the other islands, notably Montserrat, about the time referred to also showed more bacterial infections than usual. The close association of these infections with the wet period suggests a connexion between the two. The occurrence indicates a possible explanation of the difference between Lewton-Brain's observations and those of Bartlett and myself.

Cultures of bacteria have been obtained from bolls from four different islands, and from several separate plants in St. Vincent.

The colonies obtained on nutrient agar have been either (a) distinctly yellow and wrinkled or (b) whitish-buff and smooth,

with a rather pearly lustre. Very little further work has been done in this direction as yet, owing to the end of the season having been reached. Tentative efforts to produce angular leaf spot or bacterial boll disease by means of the cultures have been unsuccessful.

Recent Experiments.

During the visit to St. Vincent already referred to, a number of experiments designed to afford further information as to the course of the disease and the nature of its connexion with plant bugs were instituted by the writer, assisted by Mr. Harland. In most cases the bolls were forwarded to me in Barbados later for the purposes of examination. Owing to delays in transit some of the material was in poor condition when it was delivered, and the numbers cited in the experiments are consequently small owing to the elimination of decayed bolls. For this reason the results of the individual experiments cannot usually be regarded as decisive, but in the experiments as a whole the connexion of the disease with bug punctures was clearly and directly established, and some points of interest with regard to the affection were demonstrated.

Experiment 7.

Stainers and green bugs enclosed in cambric bags on green bolls of an isolated plant, upon which no bugs were seen, and of which several bolls examined were uninfected.

A. *Nezara viridula.*

Boll 1. Nov. 20: two bugs enclosed.
Nov. 22: bugs alive and active. At least a dozen punctures visible inside, more outside. No proliferation. Punctures ringed outside with a collar of hardened gummy exudation; a slender projection of similar material within. In section a distinct and regular channel 43 microns wide; wall golden yellow. Some (presumably the fresher) punctures show a small green water-soaked spot on the inner surface of the carpel, others a small brown dot with a corresponding dot on the lint.

Boll 2. Nov. 20: two bugs enclosed.
Dec. 20: boll still green. Very heavily punctured all over, with considerable proliferation. Several seeds are killed. There is little staining. Two brown spots of small diameter on the lint are infected with Nematospora (D).

B. *Dysdercus delauneyi.*

Boll 1. Nov. 20: stainers enclosed.
Nov. 22: stainers escaped, sound boll, unpunctured.

Boll 2. Nov. 20: stainers enclosed.
Dec. 20: heavily punctured on one side, and much proliferated. No staining.

Remarks: Afforded information as to the early appearance and effects of punctures; shows that heavy proliferation of the pericarp, and injury to seeds sufficient to cause their death, may ensue from severe insect attack without the co-operation of an infecting organism, and without producing staining in well developed bolls.

EXPERIMENT 8.

November 21. Green bolls pricked through to lint in one carpel with a fine sterile needle; remaining carpels left as controls. Bagged.

A. Washed with mercuric chloride solution 1/1,000 before pricking.

Boll 1. Nov. 24 : Punctures clean. No staining.
2. Dec. 15 : Open. No staining.
3. Dec. 15 : Open. No staining.

B. Pricked without washing, and bagged.

Boll 1. Nov. 24 : Punctures visible as slight brown dots inside ; a little light yellow staining ; no infection detected.
2. Nov. 24 : Punctures visible inside. No staining.
3. Dec. 15 : Open ; lint clean.
4. Dec. 15 : Open ; lint clean.

Remarks : Designed to show presence or absence of infecting material on surface of boll. Numbers too small to be of much value as negative evidence.

EXPERIMENT 9.

Infection trials with material from agar cultures of Nemato spora (Species D). Made November 22, examined December 15.

A. Material spread over surface of boll, which was then pricked through to lint, and bagged.

Boll 1. Green, punctures still open externally, internally they show as yellow dots on endocarp, with corresponding dots on lint. Otherwise no effect.

B. Bolls pricked, then smeared with fungus and bagged.

Boll 1. Green, two rows of punctures externally visible ; internally, two corresponding rows of proliferations, some of which are large ; they are nearly white, with a few small brown dots on some of them. The lint is only stained to the extent of corresponding brown dots. No infection detected.

2. Dry and open, but effect can be recognized as being of same type as previous boll.

3. Punctures visible within, penetrating endocarp, proliferation absent ; very slight staining opposite punctures ; no infection detected.

C. Bolls inoculated with a needle and bagged.

Boll 1. Six punctures, of which two have caused proliferation. One of those without proliferation has produced a general infection of the lint on the corresponding seed, which is stained light yellow and infested with the fungus. The remaining punctures have produced only brown dots as in B 1.

Remarks : Attempts to produce infection from fungus material applied externally to punctures in the boll were unsuccessful. Infection was produced in one case out of six in which it was attempted to introduce the fungus on a needle.

EXPERIMENT 10.

Infection trials with material from agar cultures of a bacterium obtained from internally diseased boll. Made November 22, examined December 15.

A. Bolls smeared with culture and pricked through.

Boll 1. Green, sound outside. The punctures are marked within by slight cracks in the endocarp over small swellings. The lint is heavily stained in corresponding patches, which are heavily infested with bacteria.

2. No infection, no staining.

3. Punctures show through as in (1) above, one is marked by slight poliferation. Severe bacterial staining of the lint is located definitely under the punctures and spreading across the suture line. Remainder of boll quite clean.

B. Bolls pricked and then smeared with culture.

Boll 1. Green. Punctures faintly visible, inside, one slightly proliferated. No infection or staining

2. Half dry. Each puncture penetrates the endocarp, which shows a slit in most cases, with a few loose cells projecting. No infection; the lint under each puncture shows the usual brown dot.

3. Green. Situation of punctures marked by slight internal swelling but the endocarp is not penetrated. The largest swelling has a brown pocket in the line of puncture, filled with bacteria. No staining.

C. Bolls pricked with a needle dipped in a culture. In this series the punctures were made too lightly and did not penetrate to the lint. In one case a bacterial pocket as in B 3 was produced in the boll wall.

Remarks: Infection was obtained, and the disease reproduced, when the boll was first smeared with bacteria, then pricked; it was not obtained when the order of these operations was reversed. So far as the experiment goes the indication would seem to be that it is necessary for the bacterium to be carried through the boll wall into contact with the lint for infection to take place.

Experiment 11.

It is worthy of note that in Experiment 10 no cases of the external bacterial boll disease could be traced to infection with the bacterium used. An attempt was made to infect the underlying lint by pricking through the water-soaked spots which mark the first stage of the external disease with a fine needle; no infection was obtained. It is however common knowledge that when the lesion of bacterial boll disease extends through to the lint the latter becomes infested with bacteria and with secondary fungi which develop on the diseased spot and is badly stained and often rotted.

Experiment 12.

Stainers enclosed with bolls washed with mercuric chloride solution, and with untreated controls.

A. Treated bolls.

Six were examined, of which three were dry. There were no bug punctures in the green bolls, and no visible sign of such in the dry ones. There was no stained lint in any of the bolls.

B. Untreated bolls.

Boll 1. Dry; infested with pure Nematospora and badly stained.

2. Dry; clean.

3. Green; very severely punctured; infested with bacteria, Nematospora and Eremothecium, and completely stained.

4 and 5. Enclosed together; green; infested with Eremothecium in small local patches clearly traceable to punctures.
6. Green; four punctures, with a local patch of Nematospora under each.
7. Green; very numerous punctures; severely infested with Eremothecium, and one patch of Nematospora.

Remarks: No infection occurred in six treated bolls; of seven left untreated six were severely affected. The treated bolls were so far as could be ascertained unpunctured by bugs, the controls were more or less heavily punctured. The influence which appears to have been exerted by the treatment was thus not due to the sterilization of the surface of the boll, but to the prevention of stainer attack. Further experiments to confirm and elucidate this effect will be carried out on the first opportunity.

EVIDENCE FROM INDIVIDUAL BOLLS.

A selection of cases is here given which further illustrate the effects of bug punctures.

1. A green sound boll. Several dots indicating bug punctures visible on the endocarp, these are sterile. At another point there is a round stained patch 5 mm. in diameter directly under a puncture. The track of the puncture was sharply defined, in a section made parallel to its course, as a channel 70 microns wide. The projecting matter at its inner end contained Nematospora material, and the stained patch corresponded with a pure colony of this fungus.
2. Green boll, with three superficial water soaked spots. Several bug punctures, of which two have small local bacterial infection under them.
3. Green sound boll. About twelve bug punctures visible within as small green dots with a yellow projection from the actual puncture. Only one of these introduced infection, a small colony of Nematospora being connected with it.
4. Green sound boll. In one carpel, two proliferations connected with punctures, in each of the two remaining carpels, one proliferation. A pure local patch of Nematospora is situated under each. The surrounding lint is perfectly clean.
5. Green sound boll, enclosed with two stainers kept without food for several days. Punctured all over, so thickly that the surface is drying up in patches apparently from this cause. Heavily infested with both fungi.
6. Green boll, with a large proliferation but no infection and no staining.
7. Green boll with one proliferated puncture. The lint in contact with it is water-soaked but not infested and not stained.
8. Young green bol. One carpel has six punctures in two groups of three, one group proliferated, one not, and a single puncture, not proliferated. The seeds under the punctures show a red-brown spot on their surface, and the lint protoplasm is brown and dead for several millimetres about the spots. The lint was carefully examined, and showed no infection.

EXPERIMENT 13.

The beaks of freshly caught cotton stainers were clipped off with sterile scissors; each into a tube of sterile nutrient agar.

Fifteen tubes were examined, in none of which was any of the internal boll disease fungi recognized. Eight tubes developed both bacterial and fungus colonies in connexion with the beaks, three bacteria alone, and three fungi alone. One was sterile.

The operation was carried out by Mr. Harland at the Experiment Station, St. Vincent, in March, with tubes supplied

by the writer. The conditions of the experiment were not very satisfactory, as owing to various delays the medium was too dry for good development of the organism obtained.

III. CONCLUSIONS FROM THE EXPERIMENTAL EVIDENCE.

THE DIRECT EFFECTS OF BUG PUNCTURES.

The internal appearance of bolls damaged by plant-bugs is described by Morrill,[12] with reference to members of the Pentatomidae Coreidae and Pyrrhocoridae, as follows:—

The most essential factor in determining injury to cotton bolls by these plant bugs is the appearance of the inner side of the carpels, where the point of entrance of the insect's setae is marked by a minute dark spot surrounded by a watery or blisterlike, bright-green area, contrasting distinctly with the light, dull-greenish background. In many cases, particularly in bolls three-quarters grown or more, these blisterlike areas increase to a diameter of 4 or 5 millimetres, but in other cases, more especially in small rapidly growing bolls, a physiological reaction in the form of a proliferation of plant tissue takes place.

The objective point of the attack by the insects investigated is the seed, which they are able to reach with little difficulty by means of the threadlike organs of their mouthparts, except in large, nearly mature, bolls which are protected by the resistance offered by the lint. Except in the largest sized bolls, therefore, a blisterlike spot or a proliferation on the inner side of the carpel, such as has been described, indicates an injury to the seed or discoloration of the lint directly opposite. When the seed of a rapidly growing boll is fed upon, at first the stimulation, probably partly mechanical and partly due to salivary fluids of the bug, causes an increase in the flow of sap to the injured seed, causing a characteristic watery appearance. The seed afterwards becomes discoloured and proliferous tissue is extruded from it in some cases. The lint surrounding the point where the insect's mouthparts enter turns yellowish, and if the injury is severe, finally becomes a dirty brown and decays.

This account applies exactly to the effects of punctures by green bug and cotton stainers as observed by the writer. The decay mentioned in the last sentence quoted is presumably the result of infection. Apart from this the effects described can be produced as direct results of insect attack, without complication by invading organisms.

There is a considerable range of variation in the results produced in this way. No systematic experimentation has been directed to the subject, but the conclusion has been reached that only in quite young bolls is any notable staining of the lint effected by uncomplicated punctures. Boll No. 8, in the section headed 'Evidence from individual bolls' affords a typical instance of the damage fairly frequently observed in young bolls, i.e. a brown spot several millimetres in diameter. Results more severe than this have only been observed in the somewhat rare cases when one or more seeds have been killed outright at an early stage of growth. In bolls approaching full size the commonly observed effect is that described under Experiment 7 A, boll 1, consisting only in a brown dot on the lint against the puncture. This is the case even when large proliferations are formed.

The experiments show that proliferation is a simple wound response, not dependent on infection or on any injection by the

bug, since the proliferated tissue is frequently sterile, and can be produced in response to injuries made with a needle. A proliferation consists of a mass of thin-walled parenchyma, produced by tangential division of a group of cells of the mesocarp. The base shows a constriction where it passes the tough endocarp, and then the structure spreads out into a spongy mass, with the cells on the surface very loosely associated. In Sea Island bolls such a mass may remain small or attain to a diameter of about 1 centimetre ; in perennial cottons the loculus is not infrequently nearly filled by proliferated tissue. Large numbers of bug punctures remain free of any such development, and in the case of needle punctures made in the same boll at the same time some have caused proliferation and others not, without any indication of the reason for the difference appearing on examination.

There seems to be no relation between the occurrence of proliferation and the infection of the boll contents. Proliferated and non-proliferated punctures alike may remain sterile or be associated with colonies of the intrusive organisms which give rise to internal boll disease.

The Method of Infection.

The certainty with which the perforations made in the boll wall by bugs can be recognized, and the clear association with such perforations of all the localised infections seen in otherwise sound bolls, place beyond doubt the connexion between bug injury and the internal boll disease. There is no evidence to suggest that the disease ever arises under natural conditions in any other way. Infections of the lint which take place as a result of bacterial or fungus infestations of the boll wall are not included by the definition of the disease, and, so far as the fungi at least are concerned, are not due to the same invading organisms.

The manner in which the infecting organisms of internal boll disease attain to their position within the boll has not yet been established. The alternatives which suggest themselves are (a) that the infecting organisms exist in some form on the surface of the boll, which they are able to enter when an insect perforation affords a channel, (b) that the infection is conveyed by the bug itself.

The evidence so far obtained is not decisive. Experiment 2 afforded a few examples of infection following perforations with a needle, but the wounds were very much larger than those made by bugs ; there is no evidence that the needle was sterile, and the organisms could not at that time be recognized. In the later experiments simple needle pricks (made with the finest steel wire obtainable) did not lead to infection in the few cases examined, nor was infection obtained when the boll was smeared with a culture of Nematospora, or when appropriate bacteria were smeared on after pricking. In the case of both organisms the infections obtained took place were under conditions which permitted of infected material being carried down by the needle.

Consideration of the general circumstances greatly favours the idea of insect carriage in the case of the fungi, that of the

bacteria being more doubtful. The fungi concerned have only been found in fruits, for existence in which they appear to be specially adapted. There is no sign of their presence on any other part of the plant. Their spores adhere very tenaciously, in masses, to the lint of infested bolls when they open, so that it is impossible to conceive of their carriage by wind from this source in such profusion as would be necessary to secure their general distribution. Yet infections take place with great readiness when bugs are placed on the bolls of previously unattacked plants, confined in sterilised bags of close-textured cambric, (90 x 100 threads per inch).

The Incidence of Infection.

Examples have been quoted above which show (a) that bolls may be severely attacked by stainers without infection ensuing, (b) that out of many punctures in a boll only one or two may lead to infection, (c) that in a boll with several punctures each one of them may produce a separate infection. This corresponds with certain field experiences of the relation between stainers and the disease. In December 1915 stainers were fairly plentiful at the Experiment Station, St. Vincent, when there wes very little internal boll disease in evidence. On other occasions at the same Station when stainers have been kept down to small numbers by careful daily collection, the incidence of the disease has been severe.

Dr. H. A. Tempany, Superintendent of Agriculture for the Leeward Islands, reporting in May 1916 on a visit to Barbuda, compared the conditions found there with those on two Antigua estates visited about the same time In Antigua, although cotton stainers were fairly prevalent and had been so for some time, the loss was small and usually confined to a small portion of the boll contents. In Barbuda the losses were much more serious, although stainers had not been present in any considerable numbers at any time during the season.

Where the disease is prevalent when stainers are few there is always the influence of the little-noticed green bug to be reckoned with, but the existence of the opposite condition appears to show that the incidence of the disease depends on the availability to the insects of sources of infection. Weather conditions appear to have no controlling influence on the fungoid type of infection.

Since the conditions existing within the bolls, and the habits of the insect, are believed to be stable, the differences found may be regarded as due to influences affecting the third factor, the infecting organisms. So far as evidence is available, early appearances of stainers do not produce much infection ; reported cases of severe damage have always occurred late in the season, which suggests that cumulative effects are built up in the cotton crop by transmission of the disease from boll to boll.

There being usually a period of some weeks or months, in Montserrat and St. Vincent particularly, during which cotton bolls are not available to the stainers, attempts have been made to find the fungi concerned in the fruits of the common

alternative food-plants of the insect. Mr. W. N. Sands,[16] Agricultural Superintendent, St. Vincent, has observed definite migrations to and from silk-cotton and mahoe trees, and has forwarded fruit from these trees after stainers have infested them. Vigorous proliferation, and injury resulting in the death of many seeds, have been evident. Except in one doubtful instance of a preserved mahoe fruit, where Nematospora was detected, but only on a cut surface, the damage has not been found to be associated with intrusive organisms. Sands has reported the internal rotting of silk-cotton fruits, but examples of this have not been seen by the writer.

The effects of the campaign of eradication against these two trees, decided on by the St. Vincent Government and conducted with great energy by Mr. Sands, should afford evidence on the point under discussion. Mahoe trees to the number of 11,570, and 1,552 silk-cotton trees, with thousands of seedlings in addition, were removed between August 1916 and July 1917.

IV. THE INCIDENCE OF THE DISEASE.

Although the necessary agents of the disease have been shown to be generally distributed, there are very wide and striking differences between the cotton-growing islands in the extent of the losses experienced, and these differences are relatively stable. They can be shown to depend principally on the relation between :—

(a) the time of planting,
(b) the length of the crop period,
and (c) the time when infestation with stainers takes place.

There are also subsidiary factors :—

(d) the prevalence of green bugs,
and (e) the proportion of punctures infected,

but the evidence is not in general exact enough to trace the effect of these.

THE RELATION BETWEEN CROP CONDITIONS AND LOSSES FROM THE DISEASE.

Harland[9] has followed out in detail the development of the 1916 cotton crop at the St. Vincent Experiment Station. Reference to the curves of flowering and bolling thus obtained shows the existence of two distinct periods, produced by the flowering of the primary and secondary branches, respectively. The first falls almost to zero before the second begins, but there is no appreciable interval between them. The course of the flowering curves is followed at an interval of fifty to fifty-five days by the curves representing the ripening of the bolls, the two flowering periods being represented in the two ripening periods, known to planters as the first and second pickings.

Harland notes that the first flowering curve is not symmetrical, because of the introduction into its second half of the flowers beginning to be produced from sympodia on the secondary branches. The increase of this factor presumably accounts for the experience that under conditions which enable

the plants to develop rapidly the first picking may be greatly increased at the expense of the second. Robson gives the following figures with regard to plots at the Montserrat Station and a plot grown under very favourable conditions on an estate field. The yields are of seed-cotton, calculated to the acre :—

	First crop.	Second crop.	Total.
Experiment Station 1914	896	776	1,672
„ „ 1915	1,348	241	1 592
Estate 1915	1,508	...	1,508

It will be seen later that this point is of importance in connexion with the possibility, in St. Kitts and Montserrat especially, of securing a satisfactory return from the first picking alone and thus escaping serious damage from internal boll disease.

In islands where no close season is enforced a practice has been adopted by some growers of leaving the plants after the second picking for the sake of the new growth, from the base or from dormant buds on the axis, which takes place in the Spring. For this the term ratoon cotton is often used and may conveniently be adopted. If the field is to be put back into cotton the land has of course to be cleared in time to allow of preparation for the new crop, but the operations of clearing and replanting often come close together. When, as is often the case, the land is not wanted until late in the year, for cane planting, the old cotton may be allowed to stand for weeks in proximity to the new, and the facilities for the transference of pests and diseases are perfect.

The prevailing conditions and practices in the different islands, so far as they can be generalised from the information available, may now be reviewed. It will be understood that there are many variations due to differences in situation and to individual preferences.

ST. VINCENT. Judging by the experience of the last two years, and applying the knowledge now gained to the records of previous years, it becomes evident that of all the islands St. Vincent has been subject to by far the heaviest and most regular losses from the disease under consideration. The primary reason for this is clear. Whereas in the other islands the tendency from year to year has been towards earlier planting, working back so far as suitable rains have permitted, from June to May, April and even March, in St. Vincent such a course is rendered unprofitable by the heavy rains usually experienced in August, September, and early October. To escape to some extent the heavy losses from shedding experienced in May-planted cotton during this period, planting has been carried out in June and July. The result is illustrated by Harland's study of July-planted cotton at the Experiment Station. The second picking, which with a first crop usually seriously reduced by rainy weather would often be the greater, reaches its maximum

towards the end of December. But the middle of December is about the time in St. Vincent when cotton stainers get completely out of control. By the end of December, in Harland's experiments, it was scarcely possible to find a boll unaffected by the internal disease.

In early January 1916, the writer saw a field of late cotton which was in excellent condition and crowded with well-grown bolls, but infested with stainers. From the maturing bolls in sight it should have given at least 150 lb. of lint to the acre: actually, owing to the internal boll disease, the yield of clean lint from the 5 acres was 10 lb.

The result is that, as a consequence of internal boll disease, returns in St. Vincent largely depend on a first crop which is rendered precarious by the local climate. In the conditions imposed by the heavy Autumn rainfall the control of stainers is vitally necessary to secure the stability of the St. Vincent cotton industry, upon which at present the prosperity of the island largely depends.

ST. KITTS. As affording the stongest contrast to St. Vincent, the case of St Kitts may conveniently be considered next. St. Kitts has a well-established sugar industry, and nearly all the arable land is occupied by estates as distinguished from small holdings. On the estates cotton is generally grown as a catch crop between the reaping of sugar-cane in the early months of the year and replanting in December or January.

In the principal (southern) area it is usual to plant with the first rains of May, which gives a first crop in September and October. The requirements of cane planting prevent the keeping of this catch crop cotton for a second picking. The system makes the crop dependent on the weather of a restricted period, but in normal years the distribution of the rainfall is favourable, and very satisfactory returns are secured. In the northern area of the island the rains are heavier, and to escape them it is customary to plant even earlier, in March and April.

There is a relatively small amount of long-term cotton grown, which may be kept on indefinitely into the first half of the following year. It is to this cotton, in its late stages, that stainer infestation and internal boll disease are practically confined. There may possibly be a small amount of the disease in the short-term crop, but none has been detected by general methods of observation.

MONTSERRAT. Montserrat[15] is interesting as affording examples of damage fluctuating widely in response to differences in time of planting, duration of crop, and period of infestation. Until recently reliance has been mainly placed on the first picking; the second, coming mainly in January, has been liable, as shown in examples already cited, to very severe losses from internal boll disease. The position was like that of St. Vincent, with the difference that the first picking has usually given much better returns in Montserrat as a result of the smaller rainfall.

There is now a strong movement towards the securing of a good part of the second picking by planting very early, by keeping stainers in check as long as possible by hand collecting, and in some cases by the destruction of alternative food-plants. Cotton

planted in March or April should give the bulk of its second picking in November or December. It is in these months that stainers become prevalent, but the bolls escape attack in their earlier, more susceptible stages, so that the staining is limited in amount even in infected locks, and a valuable proportion of locks may be quite clean.

The feasibility of early planting depends on the occurrence of a fall of rain suitable for the operation, which as a rule is more to be depended on in windward than in leeward districts.

Early planting is not without its drawback, which lies in the increased possibility of prolonged dry weather after planting. The risk of this appears to be well worth taking in order to extend the bearing period in places where internal boll disease tends to shut down the yield by the end of the year, as in Montserrat and Nevis. The climatic conditions of St. Vincent are believed to render the measure impracticable there.

It is to be noted that unexpected opportunities for early planting are often lost owing to unreadiness or indecision.

NEVIS. The conditions in Nevis seem, so far as they have been recorded, to be comparable with those in Montserrat, with the difference that there is no close season, and old cotton is often left standing until June or July, either from neglect or in hopes of ratoon growth.

A law has now been passed according to which an aggrieved person may demand the clearing of old fields likely to serve as a source of infection.

ANTIGUA. Mr. J. Jackson, Curator and Agricultural Superintendent, reports that according to present practice the planting season extends from May to September. Sometimes the earlier, sometimes the later-planted cotton gives the better yield : it depends entirely on the weather experienced.

As a general rule most of the crop is obtained from the first pickings, but under certain conditions excellent second pickings are obtained ; this is however exceptional. There is as a rule no ratooning practised. The main crop is reaped between the months of December and March, but the very early cotton comes in from about the beginning of October.

Internal boll disease has not been recognized as responsible for notable losses in Antigua except in occasional local instances. The small proportion of stained cotton in the annual returns (1-3 per cent.) indicates the comparative freedom of the crop as a whole from the affection. This is adequately explained by the fact that stainers do not usually become prevalent before February.

THE GRENADINES. The following observations are supplied by Mr. Harland :—

Bequia (Sea-Island).—Heavy yields were obtained in the early years of cotton growing, but recently these have been very seriously reduced, a result which is attributed to the increased prevalence of stainers and internal boll disease.

Canouan (Sea Island and Marie Galante).—The amount of stained lint has never been large, but has been reduced to a marked extent since the removal of most of the silk-cotton

trees a few years ago. Stainers appear very late in the season and are not abundant.

Union Island (Sea Island and Marie Galante).—In the Bloody Bay district where there are silk-cotton trees, the losses in some years have been considerable. In the rest of the island, where silk-cotton trees are few, the losses are small.

Balliceau and Batawia (Sea Island).—In these small islands there are no mahoe or silk-cotton trees. Although stainers are abundant there is said to be no internal boll disease. The principal alternative food-plant is the 'wild ochro' (*Malachra capitata*).

VIRGIN ISLANDS (BRITISH).—Mr. W. C. Fishlock, Curator of the Botanic Station, reports that in these islands, of which Tortola is the most important, cotton is planted at almost any time. The plants are never systematically destroyed, and remain until they die out naturally or are grubbed out for replanting cotton or some other crop. Cotton stainers do not as a rule become troublesome until about February, and the attacks are usually sporadic in character. They are as liable to appear on young cotton, planted late in the year and bearing the first flush at the time mentioned, as on old plants. Outside the period February-March-April they are comparatively few in numbers, but can usually be found in the vicinity of mahoe trees.

Internal boll disease is known to occur during the months referred to, but its incidence and extent have not yet been determined.

Influence of Wild Food-plants on the Distribution of Stainers.

The time of appearance of stainers in significant numbers, though subject to occasional variations is, on the whole, fairly regular from year to year in each island. The reasons for the differences which exist between one district and another and between one island and another, the latter well illustrated in the case of St. Kitts and its dependency Nevis, have not been closely analysed, but are generally believed to depend on the extent to which alternative host plants occur, and their situation relative to cotton areas. Proximity to bush land is well recognized as leading to earlier and more severe infestations.

Definite records are few, but there is one example from the season 1916-17 in Montserrat which may be quoted. While the general average of stained cotton for the island crop worked out at 7·7 per cent., the return from the ginnery of a district adjacent to bush land and subject to early infestation was 24 per cent. A considerable part of this increase was believed to be due to internal boll disease.

It is noted in Tortola that the areas first infested are those nearest to the seashore, a fact which is believed to be correlated with the occurrence of the mahoe tree, which is very common on sandy beaches.

There is strong local opinion that the practice, particularly common in Nevis, of leaving the old cotton plants standing in

the fields to a late period, helps greatly to carry over stainers from one crop to the next. Such fields have been reported as swarming with the bugs although there were very few bolls present, at the time when the new plants were developing.

Sands[16] made observations on the migrations of stainers in St. Vincent in 1916. The cotton plants were mostly destroyed by the end of February, and the stainers which were present on them in large numbers moved to surrounding vegetation, being observed feeding, but not breeding, on various flowers and fruits. According to this observer, the two plants upon which the stainer breeds in St. Vincent during the succeeding period, and which are common enough to serve to carry over the insect in numbers, are the silk-cotton (Eriodendron) and the mahoe or John Bull (Thespesia).

In March, when the bolls of the silk-cotton tree began to develop, swarms of mature insects in flight were seen approaching the trees, upon which they settled down and soon began to breed. Towards the end of April the bolls were ripe and scattering their seeds, on which lesser numbers of the insects continued to maintain an existence for some time.

Where there were no silk-cotton trees the bugs seemed to migrate from the cotton-fields direct to the mahoe, which flowers freely from February to April, and continues to flower with more or less irregularity through the year. From April to August thousands of the bugs, mature and immature, were observed feeding on the young and old fruits. Cotton planted in April close to some of these infested trees was found badly attacked by internal boll disease in July.

Robson[15] states the conditions in Montserrat to be as follows :—

After the destruction of the old cotton, which is compulsory at the end of January, the insects are able to survive for a time on a large number of both wild and cultivated plants, but by the time the next cotton crop is planted, about the month of May, they have so far been noticed to exist only on certain native plants, which include the mahoe, the silk-cotton tree, and a number of shrubby and herbaceous plants belonging to the order Malvaceae. [According to specimens forwarded the latter consist of species of Sida]. Towards the end of July or August some of the insects evidently migrate from their native hosts and find their way into the cultivated fields of cotton.

Evidence of migration is afforded by an experience at the Grove Experiment Station, Montserrat. On two small plots totalling 0·35 acre, planted in April, stainers were first noticed in July. During that month over 7,000, all adults, were collected. There was no general infestation of cotton in the neighbourhood but there was a similar invasion in a field about half a mile away. The numbers fell to insignificance in August and the regular infestation did not begin until October. In the middle of that month young bugs were first seen, and by the end of it the insects were arriving in uncontrollable numbers. The amount of internal boll disease resulting from the first attack was small.

According to Robson, 'when the insects are first noted in cotton fields, they appear to be congregated on small areas, and seem first to invade the same section of a field, if cultivated in this crop, year after year.'

The conditions reported to exist in the small islands of Balliceau and Batawia in the Grenadines, already referred to, are of great interest, as suggesting a connexion between the absence of silk-cotton and mahoe and that of the infecting organisms which give rise to internal boll disease.

We may expect valuable information on the subject of the influence of wild food-plants to result from the measures taken towards exterminating silk-cotton and mahoe in St. Vincent.

There are indications of the possibility of placing the cotton-growing islands in two definite groups, differing in the time at which stainers become prevalent.

In St. Vincent, Montserrat, and Nevis there may be local infestations from July on, and by November or December, according to year and locality, the insects are usually widely distributed and abundant. It has been noted in several instances that this final infestation has come on suddenly, which again suggests migratory flights.

In St. Kitts stainers are reported to appear in numbers only in February or March. Reports from Tortola for the past six years are to the effect that few are to be seen until February, when they may become very prevalent in some localities. The Antigua reports indicate that stainers usually appear in moderate numbers in February and are abundant only towards the end of the season.

The islands of the first group have all large areas of scrub and wooded land, and infestation, as already indicated, is earliest in the areas adjacent to it. St. Kitts has areas of mountain rain-forest but not much scrub, and the cotton fields are relatively remote from uncultivated ground. Antigua has a good deal of scrub, much of which is of a special type, marked by the predominance of Acacia. According to information received, stainers are seldom seen in numbers on inland bush in that island. In one instance, however, referred to below, heavy losses from internal boll disease were experienced in fields recently cleared from high bush, with which they were still surrounded. Tortola is reported to have no inland plants, apart from silk-cotton trees, upon which stainers have been observed to breed.

It seems reasonable to expect that the effect of the destruction, in the islands of the first group, of the wild plants on which the stainers breed out of the cotton season will be to delay the period of infestation and produce conditions approximating to those of the second group.

It is hardly to be expected that the insects will actually be starved out in the period between cotton crops. According to Willcocks, [18] the Egyptian stainer, which has closely similar habits, is able to hold over in large numbers in a state of inactivity from December until May or later, when it is seen in abundance feeding on various plants. Extensive breeding does not begin until the cotton bolls are developed.

There is however, another possibility of relief, indicated by one or two items of evidence. It is that the removal of alternative hosts may reduce the extent of the infection of stainer punctures with fungi, to which, and not to the direct damage done by the stainer, the serious losses have been shown to be due,

THE COURSE OF INFESTATION.

Information as to the presence of the disease in the earlier part of the season is available only from Montserrat and St. Vincent.

The history of plots 1, 2, and 3 at the Montserrat Experiment Station, as presented in Table A and in graphic form below, is, taken broadly, believed to be typical for the two islands mentioned. The reduction in the number of bolls examined in late October marked the falling off of the first picking. There is no evidence to show whether the drop in the infection curve in November was due to a reduction in the numbers of stainers, or to the reduction in the number of bolls on the plants in the preceding period.

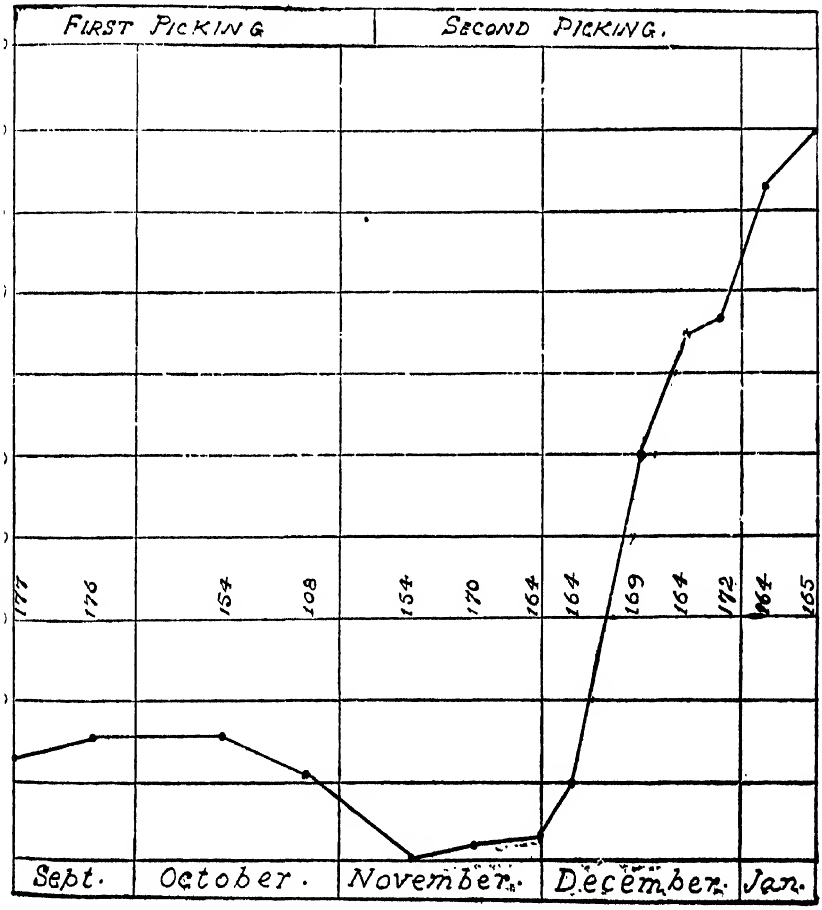


FIG 1.

Course of the disease in May-planted cotton at the Montserrat Experiment Station 1914 (see Expt. 1). The figures give the number of bolls examined.

Plot 4 shows a closely similar curve in the second picking, with no infection in the first.

The observations made by Harland at the St. Vincent Experiment Station in 1916 indicate that cotton stainers and internal boll disease were present throughout the season, the stainers having come in from silk-cotton trees in the neighbourhood. They were regularly collected (much more thoroughly than a commercial grower could afford to do) and no increase was noted in their number until the middle of December, when they appeared in overwhelming numbers quite suddenly.

At the time of my visit in November stainers were being kept down to small numbers, but were well distributed. Green bugs were in the same position. The disease was quite common, though not in itself particularly serious in view of the relatively high proportion of loss, from one cause and another, which is allowed for in this crop. Other conditions being favourable, a sufficient number of sound bolls would have been obtained to have given a satisfactory return.

Following the great increase of stainers in December, by the end of the month it was scarcely possible to find a boll unaffected by the disease. On February 10, 1,000 apparently sound green bolls were taken from the manurial plots, and of these 993 were spoiled by internal boll disease. This was about the condition of the 5-acre field already mentioned, seen in the previous year.

It is interesting to speculate on the reason for the sudden increase in the number of stainers towards the end of the year. It has been several times observed, in fact, one gets the impression from the reports that, in certain localities at least, it is the rule. There appear to be no recorded observations which throw any light on it, and it is very desirable that they should be made.

INFLUENCE ON SHEDDING.

A point of considerable importance emphasized by the study of the St. Vincent manurial plots is the influence of internal boll disease on boll-shedding. From the time of the first account by Watson already quoted, a greatly increased tendency to boll-dropping has repeatedly been associated with the disease. Lewton-Brain[11] remarks 'most commonly the diseased bolls about the time they should be opening dropped off the plants. I saw several fields which had lost every boll in this way.' Robson writing in January 1914 of an infested district reports that 'the half-developed bolls are now dropping rapidly, and only a small proportion will reach maturity in this neighbourhood.' Tempany, reporting in January 1914 on the cause of an epidemic of boll-dropping in one locality in Antigua, states that in certain fields where 75 per cent. of the bolls on the plants, though of healthy external appearance, were found to be blackened internally to a greater or lesser extent, the bolls recently fallen were affected in the same way.

Harland[9] has reached the conclusion that shedding from physiological causes does not usually extend to bolls more than ten days old, but finds that either external (bacterial) boll

disease, or internal boll disease may bring about shedding of much older bolls. His diagram showing the correlation between the diameter of the boll and the cause of shedding may be referred to on this point. Bolls to the number of 250 collected from the ground on November 16 when large numbers were being shed, were classified as follows: affected with internal disease 84 per cent., with external disease 53 per cent., healthy 14 per cent.

SUMMARY.

The nature of the affection is outlined in the introduction.

A review of the entomological literature shows that the idea once generally held that plant bugs give rise to staining of cotton by means of their excrement and through being crushed in the gins has been widely questioned, but that no convincing explanation has been offered of the extensive staining often experienced in connexion with bug attacks.

Certain pathologists have suggested that insect punctures afford means of entrance for boll-rotting bacteria.

The occurrence in the West Indies of internal boll disease as defined in this paper was noted in the year following the resumption of cotton-growing in 1902. The affection has since been found to be generally distributed in the British islands where cotton is grown, from Jamaica through the Lesser Antilles to British Guiana.

Experiments have demonstrated without exception the dependence of the disease on the infection of bug punctures. It seems most probable that, at least in the case of the fungi concerned, the infecting organisms are carried by the bugs themselves.

Under ordinary conditions fungoid infections greatly predominate over those due to bacteria, but under circumstances which appear to be connected with wet weather the proportion of the latter may be largely increased. Weather conditions have not been found to affect the occurrence of fungoid infection.

The results of plant bug attacks on the boll, as seen when the punctures have remained uninfected, are (1) the production, observed in young bolls only, of dead brown patches of lint, which are small and localized; (2) the occurrence of proliferated tissue on the inner surface of the carpels and on punctured seeds; (3) the death of a certain number of seeds in bolls severely attacked. The amount of stained lint produced in this way is negligible. The returns of stained lint obtained in these islands are mainly due, in varying proportions, to (a) internal boll disease, and (b) ordinary bacterial boll disease. The latter only becomes serious in wet weather.

The varying incidence of the disease is shown to depend in general on the relation between the time of planting, the length of the crop period, and the time when infestation with stainers occurs.

The infestation of the cotton fields with stainers originates from waste land on which their wild food-plants exist, and proximity to such a source leads to earlier and more severe invasion. Migratory flights of stainers, with an unknownrange, have however been observed.

The principal food-plants, on which the stainers breed freely out of the cotton season, are the silk-cotton tree (Eriodendron) and the mahoe (Thespesia); they also breed to some extent on various Malvaceous herbs or shrubs. They feed, without breeding, on a large variety of other plants.

The manner in which the infecting organisms are carried over from one cotton season to another is not known.

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OBSERVATIONS ON THE COTTON STAINER IN ST. VINCENT.

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INTRODUCTION.

The cotton stainer bug (*Dysdercus delauneyi*, Leth.) is the most serious insect pest of cultivated cotton in St. Vincent, not on account of the injury done by it in feeding on seed, and directly staining lint, but because of its association with certain destructive internal boll diseases. When it can be stated that these diseases following attacks of the bug occur in all districts, and have caused losses of seed-cotton, reaching in some cases as high as 96 per cent. over a large area of well cultivated and good bearing cotton land, it will be readily seen that the local cotton industry is seriously menaced. Much work has been done by Nowell[1] in connexion with the local internal boll diseases, and other experiments have been recorded by Harland[2] and Robson,[3] all of which have proved that in St. Vincent, under certain circumstances, an attack of the cotton stainer on an unopened cotton boll leads to an internal diseased condition. Ballou[4] describes the results of certain observations he made when working with *D. delauneyi*, but he did not work out its life-history, and there remained many questions concerning the life-history, feeding habits, and food-plants of this insect, on which it was desirable to obtain additional information.

In view of the serious position of the cotton industry outlined above, and the necessity of undertaking energetic methods for the control of the pest, further investigations have been made and the results are now given.

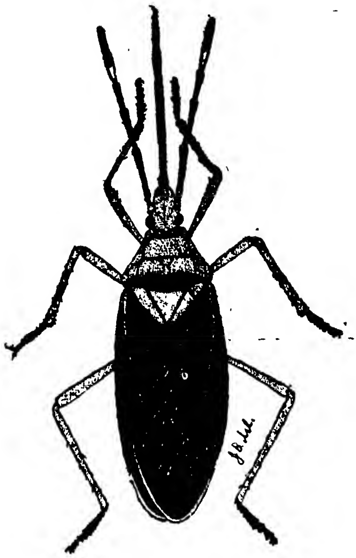

FIG. 1.

Cotton Stainer (*Dysdercus delauneyi*, Leth.). Three times natural size.

DESCRIPTION OF INSECT.

Ballou (*loc. cit.*) quotes the following translation of the description given by Lethierry in a paper 'Liste des Hemipteres recueillis par M. Delauney' à la Guadeloupe, la Martinique et St. Barthelemy,' in *Ann. de la Soc. Entom. de Belgique*, 1880, XXV, p. 10:—

'Sanguineous; antennae black (except a white ring at the base of fourth segment, and basal part of the first which is sanguineous), apical segment of the rostrum, posterior part of pronotum, all the hemi-elytra including the membrane (except fine white border of the cell), and the feet (except basal part of the femora), and the basal part of each abdominal segment black. Length, 10-12 mm.

'Variations—posterior part of pronotum and hemi-elytra fusco rubrous or obscurely red, spotted, membrane always black bordered with white. Near *D. ruficollis*, Linn., but distinct by the black bands of the ventral segments, and the general colour, which varies little.'

DISTRIBUTION.

The species occurs abundantly throughout the coastal district of the Colony. No other species of Dysdercus occurs in the island. A variety in which the hemi-elytra are red instead of black has been noted by Harland in St. Vincent and the Grenadines, but this form is comparatively rare. The bug is also found in other West Indian islands of the chain, its range extending from Montserrat to Grenada.

Life-History.

In order to study the life-history, a modification of the hurricane lamp-chimney method described by Morrill [5], and by Guppy and Thornton [6] was adopted. The lamp-chimneys were inverted and stood in lids of butter tins, and in the bottom of each chimney was placed river sand to a depth of 2 inches. The top was covered with gauze which was held in position by a rubber band. The food material for adult insects was placed on stalks or sticks 3 to 4 inches above the level of the sand, and that for nymphs on the sand. (See Fig. 2.) Water was given, when necessary, either from above or below. The breeding cages thus formed were placed in a large bow-window with an eastern aspect, so that the insects had plenty of air and sunshine. By means of a watchmaker's lens the behaviour of the insects in the cages could be closely followed.

Records were made daily between 7 a.m. and 10 p.m. from December 1916 to April 15, 1917. On certain days, when the writer was absent from headquarters, notes were made by members of the staff.

Eggs.

The eggs are smooth, ovoid, creamy white with a pearly lustre. They are slightly sticky when first laid, but freely separate from each other on drying. Ballou gives their measurements as from 1·2 mm. in length and 0·78 to 0·84 mm. in width. In the laboratory with gravid females well fed on seed-cotton, the measurements slightly exceeded those named.

The changes visible to the unaided eye, noted during incubation, are as follows: First three days contents clear. Fourth day lumpy and less opaque in part. Fifth day tinged with yellow, more particularly at the poles. Sixth day darker yellow and colour more diffused. Seventh day deep orange.

Experiments to Ascertain where Eggs Are Laid.

Many experiments were made in the lamp-chimneys in order to ascertain where females lay their eggs. These comprised tests with (a) seed-cotton; (b) old cracked cotton bolls; (c) freshly opened bolls; (d) unopened cotton bolls; but no eggs were laid anywhere but in the sand at the bottom of the chimneys. The results gave a clue to the place and manner of ovipositing in the field. It was found, as in the case of eggs laid in the chimneys, that eggs are deposited in masses in the ground, and carefully covered over, as will be described alter on.

With eggs laid in pits, and covered with ¼-inch of soil or sand, it was difficult to state exact times, but in at least three of the experiments, the incubation period was very closely ascertained, as the egg-masses were visible through the glass. It is possible that the incubation period may be shorter in cases where the eggs are not buried in the soil in a natural way: at any rate eggs kept in a dry condition in glass tubes have taken only seven days to hatch.

Laid in moist sandy soil the eggs take from seven and a half to nine days to hatch. The following table gives the results of some of the incubation tests:—

TABLE SHOWING INCUBATION PERIOD OF EGGS.

Lot.	No. of eggs.	Date laid.	Time.	Situation.	Date hatched.	Time.	No. of days.
1	55	Jan. 9	5·8 p.m.	In moist sand and covered.	Jan. 17	At night.	8
2	50–60	„ 13	3·5 p.m.	„	„ 21	Seen during day.	7½
3	50–60	„ 14	3·15 p.m. started.	„	„ 23	10 a.m.	8¾
4	50–60	„ 18	4–7 p.m.	„	„ 26	By 7 a.m.	8
5	96	Feb. 25	3–4·15 p.m.	„	Mch. 6	At night.	8½
6	56	Mch. 19	4–5 p.m.	Dry test tube.	„ 27	Early morning by 6 a.m.	7½

Frequent search for eggs on all parts of the cotton plant, silk-cotton (*Eriodendron anfractuosum*), and 'John Bull' (*Thespesia populnea*) trees over a considerable period has been without result.

In cases where adult females were confined, and could not readily obtain access to the soil, eggs have been found in and under seed-cotton in a storehouse, and in a room in a dwelling house into which the insects had wandered from 'John Bull' trees near-by. As previously mentioned, egg-laying has also taken place in muslin bags covering cotton bolls. Under natural conditions however, eggs appear to be almost invariably laid in the ground. In an old wound near the base of a large 'John Bull' tree into which sand had been blown by the wind, eggs were once found buried in the sand.

The eggs appear to be nearly always fertile, and in only one case in the large number of masses observed was there any appreciable number of infertile eggs. In the case referred to, six eggs were infertile out of the forty-five. The batch was the sixth laid. In other cases one or two eggs only in a mass showed no change after several days.

When eggs are exposed in the breeding cage, laying females will sometimes suck them even when there is plenty of other food available.

It was desirable to obtain information as to whether ants exercised any control over the cotton stainer by destroying exposed eggs. In tests made with a number of common species of field ants the following observations were noted :—

The small red stinging ant (undetermined) frequently attempted to carry off the eggs but did not succeed. The crazy ant or 'Wild Irishman' (*Prenolepis longicornis*) was strongly repelled by the eggs, both newly laid and six days old. The eggs were deposited on the ground in places where the ant was running about in search of food. On meeting an egg in its track it would suddenly stop and then run away from it, often backing and twisting round as if repulsed by some noxious odour. The common small black stinging ant (*Solenopsis geminata*) readily carried off the eggs, as also did the hunting 'tac tac' (*Odontomachus hæmatodes*).

No egg parasite has been observed. It is possible that one will be found, as in the case of the eggs of allied hemiptera, but the successful manner in which the eggs are hidden makes this appear doubtful.

Life-Cycle.

With careful attention to the food and water-supply in the lamp-chimneys it was possible to bring the young stainers through all stages of development, and over 100 were so reared.

The development of another species, *D. howardi*, which occurs in Trinidad and Tobago has been very fully described by Guppy and Thornton (*loc. cit.*), and *D. delauneyi* appears to follow it closely except in colour details which need not be described, and certain variations in length of time in the five different stages.

Life-Cycle A.

Eggs laid January 9. No. of insects, 52. Time in egg stage, 8 days.

Hatched	Jan. 17	Moulted Jan. 20 =	3 days.	1st instar.
1st moult	„ 20	„ „ 25 =	5 „	2nd „
2nd „	„ 25	„ „ 30 =	5 „	3rd „
3rd „	„ 30	„ Feb. 6 =	7 „	4th „
4th „	Feb. 6	„ „ 16 =	10 „	5th „

Total of nymphal stages ... 30 days.

Life-Cycle B.

Eggs laid February 25. No. of insects, 94. Time in egg stage 8½ days.

Hatched	March 6	Moulted March 9 =	3 days.	1st instar
1st moult	„ 9	„ „ 13 =	4 „	2nd „
2nd „	„ 13	„ „ 18 =	5 „	3rd „
3rd „	„ 18	„ „ 25 =	7 „	4th „
4th „	„ 25	„ April 2-3 =	8-9 „	5th „

Total of nymphal stages ... 27-28 days.

In order to complete the story, mature insects of both groups were allowed to pair off. In the A group, two pairs were *in coitu* on February 20, and the females laid their eggs on February 25 and 27, that is from six to seven days after pairing.

From egg to egg the period was from forty-seven to forty-nine days, made up as follows:—

Date.	Stages.	No. of days in each stage.
9.1.17.	Eggs laid	...
17.1.17.	„ hatched ...	8
20.1.17.	1st moult	3
25.1.17.	2nd „	5
30.1.17.	3rd „	5
6.2.17.	4th „	7
16.2.17.	5th „	10
19-20.2.17	Paired (1st two) ...	3-4
25-27.2.17	Eggs laid	6 7
	Total ..	47-49 days.

In the B group, from egg to egg the period was forty-five and a half to forty-eight and a half days as under:—

Date.	Stages.	No. of days in each stage.
25.2.17.	Eggs laid	...
6.3.17.	„ hatched ...	$8\frac{1}{2}$
9.3.17.	1st moult	3
13.3.17.	2nd „	4
18.3.17.	3rd „	5
25.3.17.	4th „	7
2-3.4.17.	5th „	8-9
6.4.17.	Paired (1st two) ...	3-4
13-14.4.17.	Eggs laid	7-8
	Total ...	$45\frac{1}{2}$-$48\frac{1}{2}$ days.

The figures agree closely with Ballou's estimate of the life-cycle, namely, forty-two to fifty-five days.

The dates given for the moults are those when the whole of the insects finished moulting, but some of the bugs would have moulted quite a day earlier than that given.

Before a moult the gregarious habit is strongly marked, and especially so for the later moults. The insects collect together for one to two days prior to shedding their skins. No feeding takes place before and during a moult, but it is resumed soon after.

Collections of cotton stainers not feeding, but preparing to feed, and undergoing the last moult form striking objects on bushes bordering or close to cotton fields near the end of the crop when the cotton stalks are almost bare. Plants which provide shelter from the sun and rain are preferred, and it is no uncommon sight to see thousands of stainers grouped together on a single bush. It is this habit that has given rise in part to erroneous ideas concerning the feeding habits of the insect. The writer has investigated among others, collections on wild guava (*Psidium Guava*), cacao, banana, plaintain, *Cycas circinalis*, a hedge of Euphorbia (*Canariensis* sp.?), and a shelter belt of galba (*Calophyllum Calaba*).

Dark greenish-yellow excrement was not voided until maturity was reached. In other stages the excrement was colourless or slightly tinged only. This is a point of considerable interest, because it shows that nymphs cannot cause damage to ripe seed-cotton by staining it even if they are present in large numbers. It might be stated here that the staining of cotton due to adult excrement is almost negligible both in the field and in the breeding cage. In the breeding cage the excrement was nearly always voided on the glass at the side, and not on the seed-cotton on which the insects were fed.

It was observed that young nymphs did not appear to be able to feed on unopened fruits of silk-cotton, 'John Bull', or cultivated cotton, and an effort was made to test this in the laboratory. Although the results may be inconclusive, they seem to point to the fact that in the earlier stages the insect cannot penetrate and feed through the carpels.

Fifty-one eggs were placed in a chimney, and these hatched on January 22. Unopened Sea Island cotton bolls in different stages, as well as leaves were put in. The insects were seen under the bracts on January 25. On the 28th it was noted that they were not thriving, and looked starved. By February 5 only a few remained alive, and these were constantly moving about as if in search of food. On February 11 suspicion was aroused that the seven were feeding on the dead insects, and they were changed to a fresh jar. By the 16th all were dead. Throughout, they had a starved and spidery appearance, and compared with insects of the same age fed on seed-cotton in another chimney they were only about half the size. It will be noted, however, that some remained alive for twenty days under what were evidently adverse conditions.

At the Experiment Station a number of mature insects were put in muslin bags covering unopened cotton bolls on plants in the

field. Eggs were laid in the bags. It was found when the bags were opened that all the nymphs which had hatched out were dead; this again seems to add weight to the supposition that in the earlier stages cotton stainers cannot obtain food from unopened bolls.

A further experiment was made with young stainers taken at the beginning of the fifth instar, and placed in a breeding cage with unopened bolls and leaves. It was found that in this stage unopened bolls could be pierced and their contents fed on, but the development of the nymphs was retarded, and they did not become mature until four to eight days after nymphs of the same brood fed on seed-cotton had completed their last instar.

Conclusions cannot be drawn from this small number of experiments, admittedly incomplete, but should it be proved that only mature insects or those in the fifth instar can cause a boll to become infected with internal boll disease, then an important contribution to our knowledge of the insect and of cotton diseases will have been made.

Experiments with Adults.

It has been shown in the case of specimens maturing in captivity that egg-laying commenced from nine to eleven days after maturity. Immediately after a flight of insects from one cotton field to another ½-mile away, three pairs were collected, placed in chimneys, and fed on seed-cotton. Only one pair, however, was carried through a full month. It was presumed that the insects had recently reached maturity, judging from observations of similar flights. The eggs of each batch laid in this case were not actually counted, but the information is of interest. (See Fig. 3.)

PAIR 3.—TAKEN FRESH FROM FLIGHT, JANUARY 5.

Date.	Batch number.	No. of eggs laid.	Place deposited.	Interval.
10.1.17.	1	60 (estimated)	In sand	5 days
14.1.17	2	50-60 „	„	4 „
18.1.17.	3	50 60 „	„	4 „
23.1.17.	4	40-50 „	„	5 „
27.1.17.	5	40-50 „	„	4 „
1.2.17.	6	45 (actual)	„	5 „
10.2.17.	7	11 „	„	9 „

The female died on 18. 2. 17.

A B C

FIG. 2.—Breeding Cages. (A) with seed-cotton, and bugs just mature. (B) and (C) with open and unopen cotton bolls, showing method of feeding adult pairs to ascertain where eggs were laid.

FIG. 3.—An egg mass *in situ*.

From the above table it will be seen that seven batches of eggs were laid during a period of one month, the first six at intervals of four to five days only. The total number of eggs was estimated at 296 to 336, and the egg-laying period extended over one month.

A further experiment was made, this time with insects reared in captivity, and the results of this agree in certain particulars in rather a striking way.

PAIR B.—REARED IN CAPTIVITY.

Hatched 17.1.17.

Matured 16.2.17.

Paired 19.2.17.

Date.	Batch number.	No of Eggs laid.	Place deposited.	Interval.
25.2.17.	1	96	In sand	6 days (from pairing)
28 2.17.	2	52	„	3 „
3.3.17.	3	104	„	3 „
7.3.17.	4	80	„	4 „
13.3.17.	5	56	„	6 „
20.3.17.	6	58	„	7 „
25.3.17.	7	36	„	5 „

Female died 26.3.17. being then 68 days old.
Male died on night of 21.3.17, when 63 days old.
Fresh male substituted 22.3.17.

In this experiment seven batches with 482 eggs were laid over a period of one month.

The highest number of eggs laid at one time was 104; in another experiment it was 106.

COPULATION.

As is the case with the conchuela bug (*Pentatoma ligata*, Say.) attacking cotton in the United States and Mexico, and described by Morrill (*loc. cit.*), the males are polygamous, and the females polyandrous. Feeding takes place during copulation, and also when the insects are detached. Usually a few hours before oviposition takes place the female detaches herself from the male, and searches for a suitable situation in which to deposit her eggs. After the act a few hours may also elapse before copulation is resumed. The free period can be placed at twelve hours altogether.

If this be taken as a fair average, and deducted from each interval between that given for egg-laying, the total period during which the insects were *in coitu* in the two examples given would be 31½ and 33½ hours, respectively.

Egg-Laying.

As mentioned previously, it was found that eggs were laid in the ground both in the lamp-chimneys and in the field. In the chimneys the operation was witnessed very many times. The female, on detaching herself from the male, starts to hunt about until she eventually settles on a suitable place; this was usually a level surface, and no particular preference appeared to be given to depressions, pits, or cracks. At the place selected she starts to dig with her front feet till she eventually excavates a small hole about ½-inch deep. As soon as the nest is finished she reverses, places herself in the hole, and sits almost upright in it. After the eggs are laid she gets out, and immediately proceeds to fill in the hole with particles of sand until a small but inconspicuous mound is formed over the egg-mass. The eggs are laid in a compact mass, and covered by about ¼-inch of sand; sometimes a full hour is spent in the covering operation alone. (See Fig. 3.) Egg-laying indoors has always taken place in the afternoon, evening, or night. In the field it no doubt takes place chiefly at night when the insect is less likely to be disturbed. Although fields with stainers have been closely watched for hours at a time, though not after 7 p.m., the operation has not yet been witnessed there.

EGGS.—TIME OF DAY DEPOSITED INDOORS.

9.1.17.—5-8 p.m.	25.2.17.—3-4.15 p.m.
10.1.17.—6.30-7.30 p.m.	28.2.17.—2 p.m.
13.1.17—3.30 p.m. (started).	3.3.17.—1.30 p.m.
14.1.17.—3.15 p.m. „	4.3.17—3.45 p.m.
18.1.17.—4-7 p.m.	7.3.17.—At night after 11 p.m.
23.1.17—8 p.m. (finished).	13.3.17—7 p.m. (finished).
27.1.17.—4-7 p.m.	19.3.17.—At night.
1.2.17.—At night.	25.3.17.—2.p.m. (started).
10.2.17.—4 p.m. (started).	

It will be realized from the description of the careful way the eggs are hidden, that unless the real act is witnessed the eggs would be difficult to find in the field, and this has proved to be the case. Only by carefully digging over the ground under cotton plants have they been found. In the case of a fairly large tree like the 'John Bull' it is not so difficult, and on searching the sand under infested trees, especially near the

bases of the trunks, a large number of egg-masses have been discovered.

The question of destroying the eggs in the field naturally arises. Frequent tillage might be thought to offer a means of dealing with them, as in the operation the eggs would be buried, so that the nymphs could not emerge from the soil or they would be exposed to predaceous insects. Weighing the case, however, from a practical stand-point, the method appears to offer little hope of success, as the cultivation of cotton has to be suspended at a relatively early period in order to obviate root injury.

FOOD-PLANTS.

Up to the present the cotton stainer has not been found to breed on any other species of plant except those belonging to the Natural Order Malvaceae, and the closely allied Natural Order Sterculiaceae. In the latter, however, the only representative found to be a food-plant is *Sterculia caribaea*, the 'Mahoe cochon' or 'Stave wood' tree.

The malvaceous plants other than cotton occurring commonly in St. Vincent on which the insect feeds and breeds freely are the silk-cotton (*Eriodendron anfractuosum*) and 'John Bull' or mahoe (*Thespesia populnea*). The ochroe (*Hibiscus esculentus*) is also attacked, but as the unripe fruit is the part gathered and used as a vegetable, the insect cannot make much progress on it. A few insects are occasionally found on the open fruits of the Down or Cork wood tree (*Ochroma lagopus*, Sw.). The seeds being small they provide little food, and, besides, they are greedily sought after by mice. The pods, moreover, are carefully collected by people in the month of April to obtain floss for stuffing cushions and pillows. In the Grenadines, perennial cottons, the silk-cotton tree, and the wild ochroe (*Malachra capitata*) provide suitable food for the pest throughout the year.

It should be recorded here that at the Botanic Gardens the fruits of the introduced and uncommon malvaceous trees, Tobago bread-nut (*Pachira aquatica*) and Red Kapok (*Bombax malabaricum*), as might have been expected, were fed on.

At the extreme northern end of St. Vincent, in the mountains at the back of Sandy Bay and Owia, the 'Dobarubois' (= 'Douve bois') or Stave wood tree (*Sterculia caribaea*) is found. On this tree the cotton stainer feeds and breeds in the period from February to April, as will be described later on.

In St. Vincent, for a few days when food is scarce, as is the case in certain districts after the old cotton stalks are burnt, and the above-named trees are not fruiting or near at hand, the stainer in order to sustain life, or complete maturity previous to flight in search of food, is sometimes found feeding, but not breeding, on :—

Flowers of the mango (*Mangifera indica*)
,, ,, *Eupatorium odoratum*
,, ,, Black Sage (*Cordia cylindrostachys*)
,, ,, Horse Radish tree (*Moringa pterygosperma*)
Fruit of Maiden's Blush (*Mormordica Charantia*)
Secretions of scale insects.

When observed on these flowers and scale insects, which is always in the dry months of February, March and April, the stainer appears to be seeking nectar, or honeydew, and the conclusion come to is that these substances provide the pest with its only means of obtaining the moisture necessary for its existence.

In St. Vincent all cotton plants, both wild and cultivated, are required by law to be pulled up and burnt by April 30 in each year. As a rule the cultivated cotton is finished by February, and most of the old cotton plants are destroyed by the end of this month. Planting of the new crop is started in May, provided the rains come in by this time. Although the cotton crop produces a large amount of food, and the pest breeds extensively on it during the season, and particularly towards the end of it, yet the insect could not be carried over on the cotton alone from one season to another. Investigations as to the manner in which it was able to subsist in the close season were made, and it was found that the chief nurse trees were the silk-cotton (*Eriodendron anfractuosum*) and 'John Bull' or mahoe (*Thespesia populnea*).

The following is extracted from an account by the writer[2] of the relation of these trees to the cotton stainer :—

'THE SILK-COTTON TREE (*Eriodendron anfractuosum*, D.C.).

'This large tree was found chiefly in the Leeward District on lands near to the coast, but a few trees occur in the Windward District. At the beginning of February this tree was almost bare of leaves, and only on a few trees were leaves to be seen. No stainers were present. By the end of February most of the trees were in full flower, and still no stainers were observed ; but when the young bolls commenced to swell, then the insects appeared, and in a very short time swarms of mature insects in flight, both male and female, were seen approaching the trees from all directions and settling on the bolls. In many instances the bolls were almost covered by them. Just before this happened a certain 'liveliness' was noticed among the stainers on other trees and plants, and they very quickly left these for the silk-cotton trees.

'After feeding for some time on the silk-cotton bolls, the stainers started mating. Young bugs were first seen at the beginning of April, and before any sound bolls were ripe. They were seen both on the ground and on the trees, feeding on cracked or damaged bolls, and later on seed distributed over the ground. They did not appear to be able to feed through the thick wall of the unopened fruit in the same way as the mature insects.

'On the ground, they were attracted to or hunted out silk-cotton seed over a considerable area. To give an instance, some silk-cotton bolls were cut up in an office quite 50 yards away from a fruiting silk-cotton tree which had been recently destroyed, and pieces of the bolls were thrown into a wastepaper-basket. Within three days a large number of young stainers, less than half-grown and unable to fly, found out the pieces and

started feeding on them. It was no uncommon sight to see scattered about the ground, often long distances from trees, bright-red balls made up of young stainers, completely covering and feeding on single silk-cotton seeds.

'It was towards the end of April that the bolls of the trees opened, and the seed surrounded by its floss was distributed far and wide by the wind. At the end of August there were still a number of stainers to be seen hunting about for the seed, even on the trees themselves where there were old pods, or portions of them, so that the insect was able to tide over the close season by means of the silk-cotton trees alone, for Sea Island cotton was flowering generally in August, and the pest quickly found young bolls to feed on and damage.

'A large number of bolls, picked both from attacked and unattacked trees, were examined in order to ascertain whether there was evidence of internal boll disease. As with cultivated cotton there is no external evidence that a boll has been attacked by the insect. Internally there are proliferations of the carpels, disorganized seed, and stained lint. In certain cases the state of seed and lint appeared to indicate the presence of a definite rot. In specimens forwarded to the Mycologist of the Imperial Department of of Agriculture, the fungus causing internal boll disease was not discovered. However, it is possible that the silk-cotton bolls may subsequently be found to be affected by the disease. Besides the damage described, a severe attack of the stainer may cause the silk-cotton tree to shed its bolls before full development is obtained. In one case nearly all the bolls on a tree were shed. These when examined were found to be completely disorganized internally.

'At the Experiment Station and Clare Valley Questelles, cotton stainers from fruiting silk-cotton trees were found in the cotton cultivations in June searching for food: fortunately, the season was a late one, and the cotton in most cases had not reached the flowering stage. However, at the Experiment Station, young bolls on May-sown cotton were immediately attacked and infected with internal boll disease. At Clare Valley and other places the pest found out and fed on cotton seed and cotton-seed meal, used as manure, which had not been carefully covered over with soil.

'The case against the silk-cotton tree may be summed up as follows: It is a tree which provides, when it fruits, a large amount of food for the cotton stainer, and so enables the insect to feed and breed extensively, and tide over a season when it is so important that its numbers should be reduced to a minimum for the protection of the annual cotton crop, planted in May, June, and July: therefore, it should be destroyed.'

'THE "JOHN BULL" TREE (*Thespesia populnea*, Corr.).

'This medium-sized evergreen tree is known locally under four vernacular names; these are—"John Bull", "Mahoe", "Gamboge", "Bermuda Cedar". It occurs more frequently along a part of the Windward District, which starts at Stubbs village and extends to Langley Park estate, than in any other part of the island. Its numbers are constantly being added to here

owing to the fact that the people use the branches as 'live' posts for fences, boundary marks and wind-breaks. In the Leeward District, and also in the farther portion of the Windward District, the tree has been destroyed to a considerable extent on account of its harbouring cotton stainers. It produces flowers on young shoots. The chief flowering season appeared to be from February to April, but flowers were produced on some trees almost continuously. Each flower gives rise to a fruit which ripens two months later. The ripe, leathery, circular, capsular fruit measures $1\frac{1}{2}$ to $1\frac{3}{4}$ inches in diameter and $\frac{3}{4}$-inch in depth, and contains a number of seeds, which are somewhat larger than those of Sea Island cotton. The seed is thinly covered with a short downy fuzz. The walls of the young fruit contain a yellow resinous liquid, from which the tree obtains the name of "Gamboge". The fruit never opens to liberate the seed, except by the decay of the leathery covering, and persists on the branch for a year or more before it drops off, so that in the month of April there may be no less than twenty fruits, old and young, on a small branch. By the time the young capsules are ripe the shells of those of the previous season commence to crack as a result of age, and openings appear usually roundabout the base of the fruit. The important point which it is desired to bring out here is that the "John Bull" tree at all times carries a very large number of seed-vessels containing food on which the cotton stainer can live.

'It was mentioned above that the cotton stainers left the fields about the time the cotton stalks were pulled up. In districts where there were silk-cotton trees they awaited the bolling of the trees, as has been described. In districts where there were no silk-cotton trees but "John Bull" trees, some of the stainers very quickly made their way to these trees, especially if they were close at hand. By the middle of April only a few stainers were found away from "John Bull" trees, and these were all on a few isolated trees of the "Horse Radish" (*Moringa pterygosperma*). Here they were feeding on the nectar of the flowers, but were not breeding, and not a single young bug was observed. All the evidence collected pointed to the fact that it was at the end of February that the insects left the cotton fields, or about the time the cotton stalks were being destroyed.

'From April to August there were thousands of insects both mature and immature to be found feeding on the old and young fruits of the "John Bull" trees. A favourite place for the young stainers was the old cracked fruit, and at times a swarm of them would emerge from such a fruit when opened. The people therefore state that "the pods breed the stainer bug," and it may be that the mature insects actually lay their eggs in the cracks of the old shells, and the young in hatching out feed on the seed, but eggs so laid have not yet been found. Whereas no insects were seen to be breeding on other plants examined, they were breeding very freely on the "John Bull" tree, and the conclusion arrived at was, that the tree was an even greater menace to the Sea Island cotton industry than the silk-cotton tree, and that both should be destroyed.

'Cotton planted in April close to a large number of badly infested "John Bull" trees was badly attacked in July, and a high

percentage of young bolls were found to be infected with interna boll disease when examined on July 15.

'An examination was made of the fruit of the "John Bull" tree atacked by the stainer in order to ascertain whether the insect induced a disease. No definite evidence of internal disease was found, but there were proliferations of the walls of the fruit and damaged seed.'

THE MAHOE COCHON (*Sterculia caribaea*, R. Br. et Benn.).

In no previous account of the native food-plants of the cotton stainer has this tree, known also by the names of Stave wood, Dobarubois (= *Douve bois*) tree been mentioned. This was no doubt due to the fact that the tree occurred in the mountains at the extreme northern end of the island, in a district not readily accessible. Towards the end of 1916 the writer was informed that the Caribs who resided at Sandy Bay and Owia had stated that at a certain season of the year the fruits of a tree they termed 'Dobarubois' was fed on by the pest, and this they had known for some time. A visit was paid to the district in the early part of January, and the tree was identified. At this time the tree was fruiting, but the fruits were not ripe, and there were no stainers. It was decided to pay another visit as soon as all the cotton stalks, 'John Bull', and silk-cotton trees had been destroyed, and this was done. In the meantime careful enquiries concerning the tree had been made throughout the Leeward and the lower Windward district, but without result.

On May 5, 1917, trees were inspected at Owia and Sandy Bay, but at this time all the carpids had opened and dropped to the ground. Search was made for the cotton stainer, but only a few, and these chiefly nymphs, were found on the ground. The Caribs reported that in March and April they had seen a large number of insects in the fruits, but since then nearly all had disappeared.

The Soufrière mountain was crossed next day from east to west, but not a single cotton stainer was observed on any tree or plant. People cultivating land on the slopes of this mountain, however, reported that cotton stainers were observed in March and April flying about as if in search of food, and it is possible that they were endeavouring to find the Sterculia tree, as suitable food was at this time difficult to obtain on any other tree or plant anywhere in the coast region. There is no doubt that the insect feeds and breeds on the ripe fruits of the tree in the months of February, March and April, and it is a fortunate circumstance that the fruits mature at this time.

As mentioned before, the tree has a limited distribution. It is a large straight-stemmed species with large ovate oblong leaves. The bark is collected and used by the Caribs for tying purposes, and in this way many trees, particularly young ones, are annually destroyed. The carpids, one to five in number, are borne on a long carpophore; they are semi-elliptical, hard and tough; flattened; 3 to 5 inches in length and from $1\frac{1}{2}$ to $2\frac{1}{4}$ inches breadth at the widest part. From one to six large seeds are contained in each carpid, and these average four-fifths by half an inch. The inner walls of the carpid are densely lined with stiff hairs in which the seeds are embedded. The hairs are very

irritating to the skin, and the Caribs fear to approach the trees when the carpids are opening and the hairs are being blown about by the wind.

The cotton stainer feeds on the seed at this time, and does not appear to be able to attack it before it is exposed.

OTHER FOOD-PLANTS. Information has been sought in all parts of the island regarding possible food-plants other than those described above, but nothing further has been obtained.

FLIGHTS.

In connexion with the silk-cotton, 'John Bull' and 'Stave wood' trees, mention has been made of flights of the stainer from cotton fields to these trees. That periodical flights on a considerable scale from one food-plant to another do take place there is no doubt.

At the experiment station a careful record has been kept of the number of cotton stainers collected daily in the cotton plots there.

The following table shows the number of insects collected just before and after flights:—

FLIGHT 1.

Date.	No. of cotton stainers caught.	Remarks.
July 29	76	——
„ 31	628	Flight observed this morning. Insects coming from a westerly direction.
Aug. 1	1,255	——

FLIGHT 2.

Date.	No. of cotton stainers caught.	Remarks.
Sept. 4	130	——
„ 5	395	Insects seen arriving in the morning from a westerly direction.
„ 6	1,327	——

FLIGHT 3.

Date.	No. of cotton stainers caught.	Remarks.
Dec. 13	380	——
„ 14	400	Flight observed ; direction uncertain.
„ 15	1,421	——

The cotton stainers in flights 1 and 2 were thought to come from a large number of infested 'John Bull' trees at Edinboro, about a mile away. Flight 3 was probably a migration from one cotton field to another, as on the date named, all the 'John Bull' trees in the district had been destroyed. The following notes of a flight witnessed at the Botanic Gardens seem to show that the insect does fly from one cotton field to another, in search of food.

Towards the end of December 1916, a cotton field at Montrose estate, which had almost finished bearing, was found to be heavily infested with the pest. Owing to shortage of food the insects were preparing to leave. At the Botanic Gardens, ½-mile away, there was a small plot of cotton in full bearing. Up to January 5 not a single stainer had been found in the plot, but in the early morning, between 7 a.m. and 9 a.m., a large number of insects was seen in the air flying from the direction of the infested cotton field. In a short time, by 10 a.m., the whole plot was invaded by thousands of mature insects, and almost every boll on the plants was attacked. Inspection of the cotton field from which the insects were supposed to come—all fruiting silk-cotton and 'John Bull' trees had been destroyed some time before this—showed that relatively few insects remained there.

Control or Remedial Measures.

In view of the desirability of eradicating certain of the native food-plants, a special Ordinance was passed to enable this to be done. A copy of this Ordinance is annexed (Appendix 1). The work of destruction was carried out by the Agricultural Department at Government expense. Operations were started in August 1916, and by the end of April 1917 the work was practically completed. During the period 1,542 silk-cotton trees, 11,570 'John Bull' trees and several thousand seedlings were destroyed, at a total cost of £300.

The following suggestions for controlling the pest, besides those dealing with native food-plants, are made :—

(a) A close season for cotton from February to May.

(b) The trapping of the pest by means of cotton seed, seed-cotton, or cotton-seed meal just before the cotton starts to flower.

(c) The collection of cotton stainers in the field.

In regard to (a) it is thought that if a close season for Sea Island cotton from February to May is instituted, cotton planted in the latter month would not flower before July, and there would be little food for the pest from February to July.

Natural Enemies.

There are few natural enemies. So far, the chief one observed is the 'Pipiri' or 'Hawk-beater' (*Tyrannus rostratus*). Stomachs of these birds have been examined, and each was found to contain a large number of cotton stainers. Other birds which prey on the bug to a limited extent are the 'Blackbird' (*Crotophaga ani*), and domestic fowls. A small mite, externally parasitic on the stainer, is frequently seen in the field, but appears to be of minor importance: in the breeding cages, however, it frequently caused the death of insects. Reference has already been made to certain ants which carry away exposed eggs.

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APPENDIX.

The Cotton Stainer Ordinance, 1916.

SAINT VINCENT.

AN ORDINANCE to make provision for the eradication of the Pest known as the Cotton Stainer.

[*25th July, 1916.*]

Be it enacted by the Governor with the advice and consent of the Legislative Council of Saint Vincent as follows :—

1. This Ordinance may be cited as 'The Cotton Stainer Ordinance, 1916'.

2. In this Ordinance, if not inconsistent with the context, the following words and expressions have the meanings hereinafter respectively assigned to them, that is to say,

'Cotton Stainer' means the pest known as the Cotton Stainer in whatever stage of development it may be ;

'Tree', 'Shrub' and 'Herb' respectively include the fruit or other product of any tree, shrub or herb, and the roots, trunks, stems, branches, fruits, leaves or other parts thereof, or any parts severed from any tree, shrub or herb, including emptied pods or husks ;

'Occupier' means the person in actual occupation of any land, or, if there is no such person, the expression means the person entitled to possession thereof ;

'Owner' means the person who is for the time being entitled to receive the rent of any land or who, if the same were let to a tenant at a rack rent, would be entitled to receive such rent ;

'Inspector' means any Inspector appointed before the passing of this Ordinance under 'The Agricultural Products Protection Ordinance, 1906', or an Inspector of Cotton appointed by the Governor in Council under section 3 of this Ordinance.

3. The Governor in Council may appoint some fit and proper person or persons to be Inspector or Inspectors for the purposes of this Ordinance. Any Inspector or Inspectors so appointed shall receive such salary or salaries as the Governor in Council may determine.

4. The Agricultural Superintendent, the Assistant Agricultural Superintendent or any Inspector, may without notice, and with or without assistants, at all reasonable times enter upon any lands for the purpose of ascertaining whether the cotton stainer is present on any tree, shrub, or herb or on any soil or manure, or for the purpose of searching for any tree, shrub or herb upon which the cotton stainer is accustomed to feed, and may take all such measures on such land as may be deemed necessary for the eradication of, or for the prevention of the spread of, the cotton stainer in the Colony, including in such

measures the total destruction if necessary of any trees, shrubs or herbs upon which the cotton stainer is accustomed to feed.

5. The expenses incurred by the Agricultural Superintendent, the Assistant Agricultural Superintendent or any Inspector in taking any such measures as are indicated in section 4 of this Ordinance shall be paid from the General Revenue of the Colony.

6. It shall be lawful for the Governor in Council out of moneys voted for that purpose by the Legislative Council to make grants by way of compensation or partial compensation to occupiers and to owners (according to their respective interests) in respect of trees, shrubs or herbs destroyed in order to prevent the spread of the cotton stainer into adjoining lands, in cases where in the opinion of the Governor in Council substantial damage has been occasioned by such destruction.

7. The Agricultural Superintendent, the Assistant Agricultural Superintendent, an Inspector or any other person authorized under the provisions of this Ordinance shall not be deemed to be a trespasser by reason of any entry or destruction or action taken or thing done under this Ordinance, or be liable for any damage occasioned by carrying out any of the provisions of this Ordinance, unless the same was occasioned maliciously and without reasonable cause.

8. Any person who shall in any manner obstruct or impede any person in the execution of any of the powers conferred by this Ordinance shall be guilty of an offence against this Ordinance and shall for every such offence be liable on summary conviction to a fine not exceeding twenty pounds, or in default of payment to be imprisoned with or without hard labour for a term not exceeding six months.

Passed the Legislative Council the 25th day of July, 1916, and published in the Government Gazette this 25th day of July, 1916.

NOTE:—In connexion with the foregoing paper on the life-history and habits of the cotton stainer, a short account of certain observations and experiments regarding the trapping of this pest, carried out in St. Vincent recently by Mr. Sands, may be of interest.

In spite of last year's campaign against the silk-cotton tree, a few still remained growing in situations where, if dealt with by cutting down, destruction might have been caused to valuable crops. Although these trees were ring-barked, they nevertheless fruited, and attracted large numbers of stainers from the surrounding districts. Questions arose, therefore, as to how the insects could be prevented from scattering themselves about the district, and how they could be trapped and dstroyed.

At the outset, pods of the silk-cotton tree were placed in heaps, and later cotton-seed meal, and then—what answered much better—cotton seed was further added. It was noticed that shading was necessary to obtain the best results. In regard to killing the stainers when collected, it was found that the use of kerosene emulsion or boiling water was attended by difficulties and

disadvantages. The most satisfactory means of destruction was found in the employment of a gasolene torch. The torch used was of American manufacture, and made to hold 1 quart of gasolene. It had a horizontal burner giving a long, clear, blue, continuous jet of flame under the pressure of the included force-pump. The torch was easily carried in one hand, and proved most effective, provided care was exercised that the insects attracted to the heaps were not disturbed. After a few minute's application, most of the insects were killed. It may be noted that burning does not destroy the effectiveness of the cotton seed as a trap, as kerosene oil does. A small amount of moisture to soften the cotton seed appears to be necessary to obtain the best results.

A NOTE ON RESISTANCE TO BLACK SCALE IN COTTON.

BY S. C. HARLAND, B.Sc. (LOND.),

Assistant Agricultural Superintendent, St. Vincent.

INTRODUCTION.

At the inception of the Sea Island cotton industry in the West Indies in 1903 the scale insect *Saissetia nigra*, Nietn., was recognized in several islands as a pest capable of inflicting serious damage upon Sea Island cotton. In 1905 several fields of cotton in Barbados were a total loss owing to a very severe attack of this pest.

Subsequently it has been shown that the spread of this pest can be largely diminished by destroying the old cotton plants, and by cutting out wild plants badly infested with black scale in the immediate neighbourhood of cotton fields, so that at the present time the insect only appears late in the season, and is not regarded as a serious pest.

RESISTANCE TO BLACK SCALE IN DIFFERENT TYPES OF COTTON.

So far as the present writer is aware, it has not been recorded previously that certain types of cotton show complete immunity to black scale. In the case of the Seredo cottons, introduced into St. Vincent in 1914, remarkable differences were found in susceptibility. As previously stated, all were immune to leaf-blister mite (*Eriophyes gossypii*, Banks); some were very susceptible to Saissetia and died as a result of the attack. Two types appeared to be quite immune, and for two years, although neighbouring plants became very badly attacked, they have retained that immunity.

One type has now been grown for three generations, and careful examination has failed to disclose the presence of Saissetia on any plant. It appears then, that not only do types of cotton

exist which are immune to the attacks of this scale insect, but that the immunity is inherited, being certainly genetic.

Effect of Budding on Resistance to Black Scale.

The experiment was tried of inserting a Sea Island bud into a branch of one of the immune Seredo types. The scion attained a height of about 2 feet, and after some months became very badly attacked by black scale. Other branches of the stock remained quite unaffected. When the immune type was budded on to a Sea Island stock it was apparently uninfluenced by the stock, and remained quite immune.

Breeding Experiments.

Several crosses were made between the immune types and Sea Island. The hybrids were quite uniform in morphological characters, and in respect of resistance to black scale they were nearly immune, a few scattered specimens of the insect being discovered on them late in the season.

Immunity appears to behave, therefore, as a partial dominant.

MANURIAL EXPERIMENTS WITH ARROW-ROOT IN ST. VINCENT.

BY S. C. HARLAND, B.Sc. (LOND.),

Assistant Agricultural Superintendent, St. Vincent.

Introduction.

Arrowroot (*Maranta arundinacea*) is the chief staple crop in St. Vincent. Manurial experiments with this crop have been conducted in previous seasons, but the results hitherto have not been conclusive. It devolved upon the writer by direction of the Agricultural Superintendent to lay out a number of manurial plots, the intention being to devote the plots to arrowroot alone, and to apply to each plot its own particular combination of manure year after year.

As the area available for these manurial trials was very small, it was resolved to have a large number of small plots, rather than a small number of large plots. Forty-eight plots were laid out in all, each $\frac{1}{138}$-acre in area, and the experiments were conducted with two objects in view :—

(1) To test the value of mulching with prunings of Madre del Cacao (*Gliricidia maculata*).

(2) To compare the relative values of various combinations of organic and artificial manures.

In the first experiment the number of plots was twelve; four plots were mulched and eight were left unmulched. Each mulched plot received an application of 40 lb. of gliricidia prunings. The results are presented in Table I.

TABLE I.

SHOWING RESULTS FROM MANURING ARROWROOT WITH GLIRICIDIA PRUNINGS.

No. of plot.	Treatment.	Yield calculated in lb. per acre.	Per cent. increase or decrease over average of no-manure plots.
1	No manure	6,210	-35·7
2	No manure	5,244	-45·7
3	Mulched	13,110	+35·7
4	No manure	8,694	-10·0
5	No manure	8,004	-17·2
6	Mulched	15,456	+60·0
7	No manure	11,040	+14·3
8	No manure	12,696	+31·4
9	Mulched	16,422	+70·0
10	No manure	13,662	+41·4
11	No manure	11,306	+17·1
12	Mulched	17,664	+82·9

	lb. per acre.
Average yield of unmanured plots	= 9,565 ± 7·6 per cent.
Average yield of mulched plots	= 15,663 ± 3·4 per cent.
Gain by mulching	= 6,098 (or 63·8 per cent.).

It will be seen that a very large increase in yield results from mulching, amounting to 64 per cent. A second point to notice is the progressive increase in yield from 1 to 12.

The soil of plots 1 to 5 is known to be poorer than that of plots 6 to 12, but this lack of uniformity of soil in the different plots does not obscure the effect of mulching. An increase of twice the probable error, i.e. of 16 per cent., would be significant.

In the second experiment nine different combinations of manures were applied to thirty-six plots, each combination being

in quadruplicate. In Table II will be found a statement of the yield obtained from the different plots, and a summary of the different combinations of manure applied.

TABLE II.

No. of plot.	Description of manurial treatment.	Yield of rhizomes in lb. per acre.				Average.	Per cent. increase or decrease compared with unmanured plots.
		Series I.	Series II.	Series III.	Series IV.		
1	No manure.	11,040	12,006	9,108	10,764	10,730±407	...
2	Nitrogen. 30 lb. per acre as sulphate of ammonia.	12,282	12,696	8,970	9,660	10,902	+1·6
3	Phosphate. 40 lb. per acre as basic slag.	12,558	15,732	9,798	11,178	12,317	+14·8
4	Potash. 30 lb. per acre as sulphate of potash.	12,006	12,144	10,764	12,972	11,972	+11·6
5	Phosphate (40) Potash (30)	12,558	12,282	10,764	14,766	12,593	+17·4
6	Nitrogen (30) Phosphate (40) Potash (30)	11,040	11,316	12,696	12,282	11,834	+10·3
7	Cotton-seed meal 600 lb. per acre.	9,384	11,040	14,214	12,282	11,730	+9·3
8	Phosphate (40) Potash (30) Cotton-seed meal (600)	11,454	9,660	14,352	15,456	12,731	+18·7
9	Mulched with gliricidia prunings.	14,904	10,802	15,870	15,870	14,387	+34·1

The probable error of the mean of the unmanured plots is ±407 lb. per acre, or 38 per cent.

From the average of the manured plots it is seen that with the exception of the nitrogen plot, every plot shows a gain over the unmanured plots of more than twice the probable error, and this increase is such that it can only be due to the fertilizers applied.

Plot No. 9, to which gliricidia prunings were applied, shows a gain of 34 per cent. over the unmanured plots. A complete manure consisting of sulphate of potash, basic slag, and cotton-seed meal produces the next largest increase, namely 19 per cent. In regard to the other plots it is perhaps better to take more than a single year's results as a basis for discussion.

It is certain, however, that the arrowroot grower will be well advised to apply as much coarse organic material to the soil as possible.

A NOTE ON A MODIFIED METHOD FOR DETERMINING CARBONATES IN SOIL.

BY H. A. TEMPANY, D.Sc. (LOND.), F.I.C.,

Government Chemist and Superintendent of Agriculture for the Leeward Islands,

and

R. E. KELSICK,

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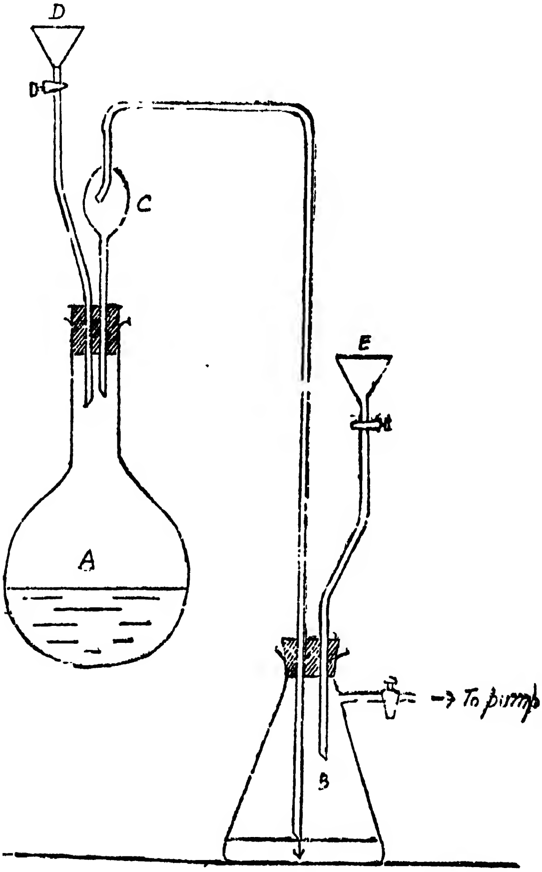
In the Appendix to the report on the 'Soils of Dominica' by Dr. F. Watts, published in 1902 by the Imperial Department of Agriculture, a method for determining carbonates in soil is described. The note in question was also reproduced in the *West Indian Bulletin*, Vol. XII, p. 69. This method has been employed in the Government Laboratory for the Leeward Islands for a number of years past and has been found to give uniformly satisfactory results. It however possesses the disadvantage that for its successful performance it requires a good deal of skilful manipulation and constant watching, while it necessitates the employment of a considerable quantity of mercury, which is expensive and often difficult to obtain in the tropics.

The following modification of this method, originally devised in the St. Kitts Laboratory by the junior writer, has been found to give very satisfactory results, and at the same time to obviate some of the difficulties alluded to above.

The modification consists essentially in the substitution of an ordinary water filter-pump for the mercury pump employed in the original form of the apparatus, and in the employment of an

ordinary suction-flask in place of the special receiver formerly used, the evolved carbon dioxide being absorbed direct in barium hydrate solution of known strength, instead of first collecting the gas and then subsequently absorbing it.

The modified form of the apparatus is shown in the accompanying sketch.



Apparatus for Determining Carbonates in Soil.

A is a strong round-bottomed flask of about 300 c.c. capacity, with a long neck, which contains the mixture of soil and acid ; B is the suction-flask receiver containing the barium hydrate solution ; this is joined to the flask A by means of a bent glass connexion provided with a splash trap C ; D and E are tap funnels intended to provide for the introduction of reagents into A and B, respectively ; while F is the side-tube connexion, with tap attached, between B and the filter-pump.

The procedure in making a determination is simple, and follows closely that adopted in the original method. A quantity of soil of suitable magnitude (in cases of feebly calcareous soils 25 grams is a convenient amount), is placed in the flask A, and to this 100 c.c. of water is added. The tap F is then opened and

the taps D and E are closed ; the filter-pump is started and the apparatus evacuated, first having seen that all connexions are gas-tight.

The tap F is then locked off, and by means of the tap funnel E, 25 c.c. of a standard solution of barium hydrate is run into B, and washed down with distilled water, taking care that no air is admitted with it.

Ten cubic centimetres of strong hydrochloric acid are then run into the flask A by means of the tap funnel D, observing similar precautions in relation to the admission of air.

The liquid in the flask A is shaken cautiously, and the flask is then gently heated until the vacuum is destroyed, and the contents begin to boil.

The pump is then started, the tap F opened, and the source of heat removed ; the liquid continues to boil under the reduced pressure while the rate of ebullition can be controlled by means of the tap F.

Owing to the strength of the acid solution in flask A, no hydrochloric acid can distil over, and the only risk consists in splashing ; this can be obviated by careful attention, while the long neck of the flask and the splash trap reduce the risk of error from this cause to a minimum.

When the liquid in the flask A has been reduced very nearly to air temperature, the tap F is closed, the tap D is opened, thereby admitting air to the apparatus, and the excess of barium hydrate present in the receiver B is titrated with standard acid. The strength of the barium hydrate solution being known, the amount of carbonates present in the soil can be calculated from the amount of barium hydrate neutralized by the evolved carbon dioxide.

Careful trials of this form of apparatus and comparisons with determinations made with the older form due to Watts have given closely concordant results, while, in relation to ease of manipulation and quickness in performing the determination, it presents considerable advantages over the older apparatus.

A NOTE ON THE DETERMINATION OF THE NON-FATTY SOLIDS IN MILK FROM THE SPECIFIC GRAVITY AT TROPICAL TEMPERATURES.

BY H. A. TEMPANY, D.Sc. (LOND.), F.I.C.,
Government Chemist and Superintendent of Agriculture for the Leeward Islands.

To the analyst working under tropical conditions the difficulty often presents itself that in calculating the content of non-fatty solids from the specific gravity by means of the well-known tables of Richmond and of Babcock, the temperatures at which the determinations have to be conducted are so far removed from those for which the tables in question are constructed, that the corrections requiring to be applied are of such considerable magnitude as to render uncertain the results obtained therefrom.

It was for many years the practice in the Leeward Islands Government Laboratory to cool milks under examination down to the region for which these standard tables are constructed, by means of ice.

Such a course while ensuring the relative accuracy of the results, possesses certain disadvantages owing partly to increased difficulties in the manipulation, and also, at times in the smaller West Indian islands, to the uncertainty of the ice supply.

In consequence, some time ago the attempt was made to reconstruct a table for the determination of the non-fatty solids in milks on the basis of a standard temperature of 30°C., which approximates to the average obtaining in most laboratories in the tropics, thereby eliminating the difficulties in question. This table has now been in use for some time, and has been found to give satisfactory results. It is accordingly reproduced in the hope that it may be of value to other analysts working under similar conditions.

In constructing this table the specific gravities were determined at a temperature of 30°C. by means of the Westphal balance, and are relative to the standard of water at a temperature of 16·6°C., this ratio being the same as that adopted in the now well-known Douglas's tables for sugar solutions. (*West Indian Bulletin*, Vol. XIV, p. 190.)

The table in question gives the non-fatty solid contents of milks corresponding to lactometer readings over a range of values of from 19 to 32 degrees, and for percentages of fat ranging between 1·4 and 6·4.

As is customary, the lactometer reading is taken as the last two figures of the specific gravity $\frac{30°C.}{16·6°C.}$, water being reckoned as 1,000°C.

The average temperature correction has been found to be equal to ·2 on the lactometer reading per degree centigrade above or below 30°C., the correction being deducted when the reading is below 30°C., and added when it is above.

PER CENT. NON-FATTY SOLIDS IN MILK.

Per cent. fat.	Lactometer reading at 30°C.												
	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1·4	6·15	6·40	6·65	6·90	7·15	7·40	7·65	7·90	8·15	8·40	8·65	8·90	9·15	9·40
1·6	6·19	6 44	6·69	6·94	7·19	7·44	7·69	7·94	8·19	8·44	8·69	8·94	9·19	9·44
1·8	6·23	6·48	6·73	6·98	7·23	7·48	7·73	7·98	8·23	8·48	8·73	8·98	9·23	9·48
2·0	6·27	6·52	6·77	7·02	7·27	7·52	7·77	8·02	8·27	8·52	8·77	9·02	9·27	9·52
2·2	6·31	6·56	6·81	7·06	7·31	7·56	7·81	8.06	8·31	8·56	8·81	9·06	9·31	9·56
2·4	6·35	6·60	6·85	7·10	7·35	7·60	7·85	8·10	8·35	8·60	8·85	9·10	9·35	9·60
2·6	6·39	6·64	6·89	7·14	7·39	7·64	7·89	8·14	8·39	8·64	8·89	9·14	9·39	9·64
2·8	6·43	6·68	6·93	7·18	7·43	7·68	7·93	8·18	8·43	8·68	8·93	9·18	9·43	9·68
3·0	6·47	6·72	6·97	7 22	7·47	7·72	7·97	8·22	8·47	8·72	8·97	9·22	9·47	9·72
3·2	6·51	6·76	7·01	7·26	7·51	7·76	8·01	8·26	8·51	8·76	9·01	9·26	9·51	9·76
3·4	6·55	6·80	7·05	7·30	7·55	7 80	8·05	8·30	8·55	8·80	9·05	9·30	9·55	9·80
3·6	6·59	6·84	7·09	7 34	7·59	7·84	8·09	8·34	8·59	8·84	9·09	9·34	9·59	9 84
3·8	6·63	6·88	7·13	7·38	7·63	7·88	8·13	8·38	8·63	8·88	9·13	9·38	9·63	9 88
4·0	6·67	6·92	7·17	7·42	7·67	7 92	8·17	8·42	8·67	8·92	9 17	9·42	9·67	9·92
4·2	6·71	6·96	7·21	7·46	7·71	7·96	8·21	8·46	8·71	8·96	9·21	9·46	9·71	9·96
4·4	6·75	7·00	7·25	7·50	7·75	8·00	8·25	8·50	8·75	9·00	9·25	9·50	9·75	10·00
4·6	6·79	7·04	7·29	7·54	7·79	8·04	8·29	8 54	8·79	9·04	9·29	9·54	9·79	10·04
4·8	6·83	7·08	7·33	7·58	7·83	8·08	8·33	8·58	8·83	9·08	9·33	9·58	9·83	10·08
5·0	6·87	7·12	7·37	7·62	7·87	8·12	8·37	8·62	8·87	9·12	9·37	9·62	9·87	10·12
5·2	6·91	7·16	7·41	7·66	7·91	8 16	8·41	8·66	8·91	9·16	9·41	9·66	9·91	10·16
5·4	6 95	7·20	7·45	7·70	7·95	8·20	8·45	8·70	8·95	9·20	9·45	9·70	9·95	10·20
5·6	6·99	7·24	7·49	7·74	7·99	8·24	8·49	8·74	8·99	9·24	9·49	9·74	9·99	10·24
5·8	7 03	7·28	7·53	7 78	8·03	8·28	8·53	8·78	9·03	9·28	9·53	9·78	10·03	10·28
6·0	7·07	7·32	7·57	7 82	8·07	8·32	8·57	8·82	9·07	9·32	9·57	9·82	10·07	10·32
6·2	7·11	7·36	7·61	7·86	8·11	8·36	8·61	8·86	9·11	9·36	9·61	9·86	10·11	10·36
6·4	7·15	7·40	7·65	7·90	8·15	8·40	8·65	8·90	9·15	9·40	9·65	9·90	10·15	10·40

DIFFERENCE TABLE.

	Lactometer reading.										
Fat.	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9	·10
·0	·0	·03	·05	·08	·10	·13	·15	·18	·20	·23	·25
·1	·02	·05	·07	·09	·12	·15	·17	·20	·22	·25	·27

The following results illustrate the application of this table in the case of nineteen samples of milk, and enable a comparison to be made between the actual non-fatty solids as ascertained by drying in the ordinary way and as found by inspection from the table :—

No.	Lactometer reading at 30°C.	Fat.	Non-fatty solids by drying.	Non-fatty solids by table.
1	24·6	4·4	8·3	8·1
2	27·4	4·3	9·0	8·8
3	26·4	3·6	8·6	8·4
4	26·8	4·3	8·9	8·7
5	26·4	5·7	9·0	8·8
6	30·0	4·0	9·6	9·4
7	28·0	4·9	9·3	8·9
8	21·8	5·1	7·6	7·6
9	24·8	2·9	7·9	7·9
10	22·3	3·5	7·7	7·4
11	25·0	3·7	8·1	8·1
12	23·3	4·3	7·5	7·8
13	27·4	4·1	8·8	8·8
14	27·5	5·5	8·9	9·1
15	22·4	3·9	7·5	7·5
16	23·1	5·5	7·8	8·0
17	26·8	5·9	8·9	9·0
18	29·5	5·5	9·2	9·6
19	27·0	3·7	8·9	8·6

HURRICANES OF 1916 AND NOTES ON HURRICANES OF 1912-1915.*

BY RICHARD HANSON WEIGHTMAN.

(Dated : Weather Bureau, Washington. D.C., February 5, 1917.)

The season of tropical storms of the year of 1916 in the West Indies was noteworthy on account of the large number of disturbances reported. In fact in only two previous years out of the last forty were more storms noted—namely, in 1886 and 1887. Besides the nine more important storms noted in 1916 there were several minor disturbances which, although locally severe, were of such short duration that it was not thought advisable to chart them. The season was also remarkable for the number of disturbances of intense character within the tropics.

Detailed descriptions of the storms that occurred during the hurricane season of 1916 are given in the issues of the *Monthly Weather Review* for the respective months, and contain all data available at the time the several numbers went to press. Data which have come to hand since the issues above-mentioned are presented in this paper, and tend to supplement rather than to change the information previously published. Deductions presented regarding origin, track, and intensity that differ from those previously given are based on more complete data. There follows a list of the hurricanes of the past season arranged in chronological order, with a few brief remarks accompanying them. An attempt is made to give a rough idea of the intensity of the disturbances noted by the use of the terms slight itensity, moderate intensity, severe intensity, etc., while an estimate of their extent is indicated by employing expressions such as slight, moderate, large. etc. It must be realized, however, that reports in most cases are widely scattered, and that estimates, such as indicated above, are in a number of cases, therefore, merely estimates. The paths of the 1916 hurricanes are shown, grouped by months on Chart X (XLIV-152) of the December issue of the *Monthly Weather Review*.

Remarks concerning the previous history of storms are based on a study of Bulletin 'X', 'Hurricanes of the West Indies' by Oliver L. Fassig.

Appreciation is hereby noted of a collection of reports from a number of the islands of the West Indies, forwarded by Dr. Francis Watts, Commissioner of Agriculture, Barbados, British West Indies, and also of numerous and valuable reports from vessels at sea.

NOTES ON HURRICANES OF 1916.

JULY 1-10.—The disturbance originated in approximately latitude 16° N., longitude 84° W., attained moderate intensity after passing through the Yucatan Channel, and reached the Gulf coast of the United States immediately west of Mobile, Ala., as a severe storm. The lowest barometer at Mobile was 28·92 inches,

* Reprinted from *Monthly Weather Review*, U. S. A. Department of Agriculture Weather Bureau.

and the maximum wind velocity (maintained for five minutes) 107 miles an hour from the east. Pensacola reported a maximum velocity of 104 miles an hour from the south-east. These velocities were records for their respective stations. The velocity at Pensacola was exceeded in the storm of October 18, 1916, a report of which follows. In a way this storm may be said to have followed an average course for the month, in that it passed to the east Gulf coast after having originated in the western Caribbean Sea.

JULY 11-15.—This disturbance, as far as reports are available, seems to have originated immediately east of the Bahamas in about latitude 24° 30′ N. It moved north-westward to the South Carolina coast, passing inland over or near Charleston, S.C. The lowest pressure reading at that station was 29·02 inches, and the maximum wind velocity 64 miles an hour from the north-east. The U.S.S. 'Hector', in latitude 31° 45′ N., longitude 78° 53′ W., reported a barometer reading (aneroid) of 28·37 inches, which, upon subsequent comparison of the instrument, is thought to be reasonably accurate. This disturbance was moderately severe in intensity, and of small area.

This is the first July storm of record that passed north-westward from the region of the Bahamas and struck the South Atlantic coast.

JULY 12-22.—The origin of this storm was in about latitude 15° N., longitude 61° W. The centre passed north-westward to latitude 29°, and thence almost due north, striking the southern New England coast with diminished energy. The lowest pressure reading, 28·94 inches (aneroid), was reported in latitude 27° 30′ N., longitude 73° W., by the S.S. 'Ausable', shortly after 1 a.m. of the 19th, with wind force 11-12. This disturbance was of moderate to great intensity, and of moderate to large area.

There is only one other storm of record in July that originated in low latitudes so far to the eastward. That storm passed westward, south of the islands of the Greater Antilles, while the storm of the present year passed north-westward, north of the Antilles.

AUGUST 12-19.—This storm had its origin in approximately latitude 14° N., longitude 56° 30′ W. It passed westward, south of the Greater Antilles, and through the Yucatan Channel, later striking the Texas coast a little south of Riviera, which is situated about 45 miles south-west by south of Corpus Christi. At Kingsville, about 14 miles north of Riviera, the lowest pressure reported was 28 inches (corrected) on an aneroid barometer, while at Del Rio, at 8 a.m. (75th meridian time) on the 19th, a pressure of 28·72 inches was observed. The highest wind velocity at Corpus Christi was about 90 miles an hour. The storm was severe, and moderate to large in extent.

This disturbance followed an average course for the type of August hurricanes that pass through the Yucatan Channel.

AUGUST 22.—The disturbance passed south of Tortola (Virgin Islands) and across the island of Porto Rico, on a course a little north of west, the lowest pressure reported at San Juan being 29·44 inches at 7 a.m., while the maximum wind velocity was

over 90 miles an hour. The origin of this storm is very uncertain, and, after crossing the island of Porto Rico, there is little if any trace of it to be found. It was of moderate intensity, and extremely small area.

AUGUST 28—SEPTEMBER 1.—The exact origin of this disturbance is unknown, but it was undoubtedly some distance to the east of the island of Dominica. The first trace obtainable is at Roseau, Dominica, over or immediately south of which city it passed about 7.30 p.m. of the 28th, with a minimum pressure reading at that station of 29·12 inches. It moved thence westward, and passed immediately north of the island of Jamaica, with greatly decreased intensity, to a position to the north-west of Swan Island, in which vicinity it lost intensity. It was evidently of small diameter and great intensity while passing over Dominica.

SEPTEMBER 4-5.—This disturbance originated east of the northern Bahamas, and moved north-west, passing to the coast near and south of Jacksonville, Fla. It was of slight energy and extent.

SEPTEMBER 20-23.—The origin of this storm was near Antigua, whence it passed north-westward, as far as can be ascertained from a limited number of reports from vessels, and recurved to the west of the Bermudas. It was of only moderate extent and slight to moderate intensity.

OCTOBER 4.—This disturbance had its origin north-east of the Bahamas, moved westward, and passed inland over northern Florida. It was of small extent and energy.

OCTOBER 7-12.—The origin of this disturbance is somewhat difficult to determine. Conditions were very unsettled, however, in the neighbourhood of the Windward Islands during the 7th and 8th. On the afternoon of the 7th there were some indications of a disturbance near and slightly to the west of Martinique. On the 8th, Roseau, Dominica, experienced a heavy sea, the breakers washing high inland, and causing some damage. On the evening of the same date the wind at Basseterre, St. Kitts, veered from north-east to south-east, and held in that quarter all day. The sea was heavy, and waves came up over the sea wall. Reports from Tortola, Virgin Islands, indicate that during the morning and early afternoon of the 9th the winds held south-east, and were light, but about 4 or 5 p.m. they increased in force. The wind was at greatest violence about 8 or 9 p.m. (100 miles an hour, estimated). After the passage of the storm the winds veered to the south and south-west to west. The following readings of the barometer were taken by Mr. W. C. Fishlock, Curator, at Tortola, Virgin Islands :—

OCTOBER 9 :—7 p.m. 29·70 ; 7.30 p.m. 29·40 ; 8 p.m. 29·10 ; 8.30 p.m. 28·90 ; 8.50 p.m. 28·80 ; 9.30 p.m. 28·94 ; 9.50 p.m. 29·10 ; 10.30 p.m. 29·20 ; 11 p.m. 29·30 ; 11·45 p m. 29·30-29·40 (oscillating) ; midnight 29·30-29·40 (oscillating).

OCTOBER 10 :—12·30 a.m. 29·30-29·40 ; 1 a.m. 29·40 ; 1·10 a.m. 29·40 ; 3 a.m. 29·58 ; 7 a.m. 29·74.

Readings made by Mr. Tanggard on the island of St. Thomas, and published in *Lightbourne's Mail Notes*, October 12, 1916, follow :—

OCTOBER 9:—7.30 a.m. 29·724; 1 p.m. 29·666; 2.15 p.m. 29·576; 3 p.m. 29·549; 5 p.m. 29·439; 6 p.m. 29·260; 7 p.m. 28·263; 9 p.m. 28·264; midnight, 29·261.

OCTOBER 10:—6 a m. 29·637; 8 a.m. 29·700.

The lowest reading at St. Croix, as reported in the *Barbados Standard* of October 12, was 28·45 inches during the night of the 9-10th. At St. Thomas and Tortola the winds veered, while at St. Croix they backed.* The disturbance evidently passed nearly over and a little to the south of St. Thomas, on a course almost due north-west, and later recurved to the north-eastward south of the Bermudas, evidenced by a report of hurricane wind encountered by the bark 'Bellas' in latitude 27° 40′ N., longitude 62° 20′ W., and by a report from the 'Aros Castle' (Br. S.S.) in latitude 25° 18′ N., longitude 63° 13′ W. According to this report the 'Aros Castle' experienced shifting south-westerly winds of hurricane force, with a barometer reading of 28·38 inches (aneroid) at 4 p.m. of the 11th. From earlier observations by the same vessel it is estimated that the aneroid read between 0·10 and 0·20 inch too low. The storm was of small area and of great intensity.

OCTOBER 12-18.—The origin of this disturbance is somewhat doubtful, although the first definite indications place it to the south of Jamaica in approximately latitude 16° N., longitude 77° W., on the 12th. It then moved to the westward, passing south of and very close to Swan Island, where barometric pressure of 28·94 inches was reported during the 14th, with winds of hurricane force. Several reports from vessels enabled the storm to be quite closely located on the 16th and 17th and show that the disturbance, after moving a little north of west during the 15th, turned sharply to the northward on the 16th and reached the Gulf coast on the 18th, very close to and immediately west of Pensacola, Fla., where the barometer reading of 28·76 inches was reported. The maximum wind velocity, reported as 114 miles an hour, constitutes a record for this station. The storm was very intense, and of moderate area.

This storm was quite remarkable for the month, in that it held a westerly course in low latitudes for four days, finally reaching longitude 87° or 88° W., before turning to the northward.

NOVEMBER 12-15.—This disturbance originated in approximately latitude 12° N., longitude 81° W., it moved thence north-westward, recurving over the south eastern portion of the Gulf of Mexico, and advanced rapidly east-north-eastward over extreme southern Florida during the 15th in the trough of a disturbance to the northward. This disturbance was evidently of marked intensity in lower latitudes, for according to press reports, considerable damage was caused to property along the coast of Spanish Honduras and in Yucatan.

*It is suggested that possibly two cyclonic centres existed in the neighbourhood of St. Thomas, thus giving rise to abnormalities.—Ed. *W.I.B.*

NOTES ON HURRICANES IN 1912-15.

Chart X (XLIV-121), in the *Monthly Weather Review* for September 1916, shows the tracks of tropical storms for the period 1912-15. A few notes, arranged by months, follow regarding these storms.

AUGUST 10-17, 1915.—This disturbance originated slightly to the east of the island of Martinique, and passed, on a course a little north of west, south of the Greater Antilles, along the northern side of the island of Jamaica. Its course then bore slightly more to the northward, and, after passing nearly over Cape San Antonio, Cuba, it advanced north-westward to the Texas coast immediately south of Galveston. The lowest pressure reading was 28·20 inches at Houston, Tex., up to this time the lowest mercurial barometer reading reported in the United States. (Record was again broken in the September 1915 storm at New Orleans.) This storm was of hurricane intensity while in the Caribbean Sea, before passing through the Yucatan Channel, as indicated by the destruction of the wireless tower and other equipment at Cape San Antonio. The storm was of great magnitude.

The track of this disturbance was not abnormal for August storms that pass through the Yucatan Channel. In this connexion, it is interesting to note that all previous August storms that passed through the Yucatan Channel have advanced without recurve to the Texas or Mexican coasts, no storm of this character ever having struck the Gulf coast east of Galveston.

AUGUST 29—SEPTEMBER 9, 1915.—As nearly as can be ascertained, this disturbance had its origin in approximately latitude 27° N. and longitude 27° W. It moved first on a course slightly north of west, passing to a position north-west of the Bermudas, whence it passed southward to the west of the Islands, then south-eastward, then westward, and later northward and north-eastward. From the evening of the 2nd to the evening of the 4th, the pressure at Hamilton ranged between 29·17 and 29·32 inches.

The track of this storm was most unusual, its recurve being blocked, and the storm forced southward by the high pressure to the northward. The storm was moderately severe, and of moderate area.

SEPTEMBER 1-4, 1915.—This disturbance originated in approximately latitude 16° N., longitude 80° W., and after passing north-north-westward over western Cuba, crossed the Gulf coast immediately west of Apalachicola. The lowest pressure recorded at the station was 29·32 inches. A pressure of 29·08 inches, however, was reported by the United States Coast Guard cutter 'Miami' off the west coast of extreme southern Florida on the morning of the 3rd. The intensity of this storm was moderately severe, and its diameter extremely small.

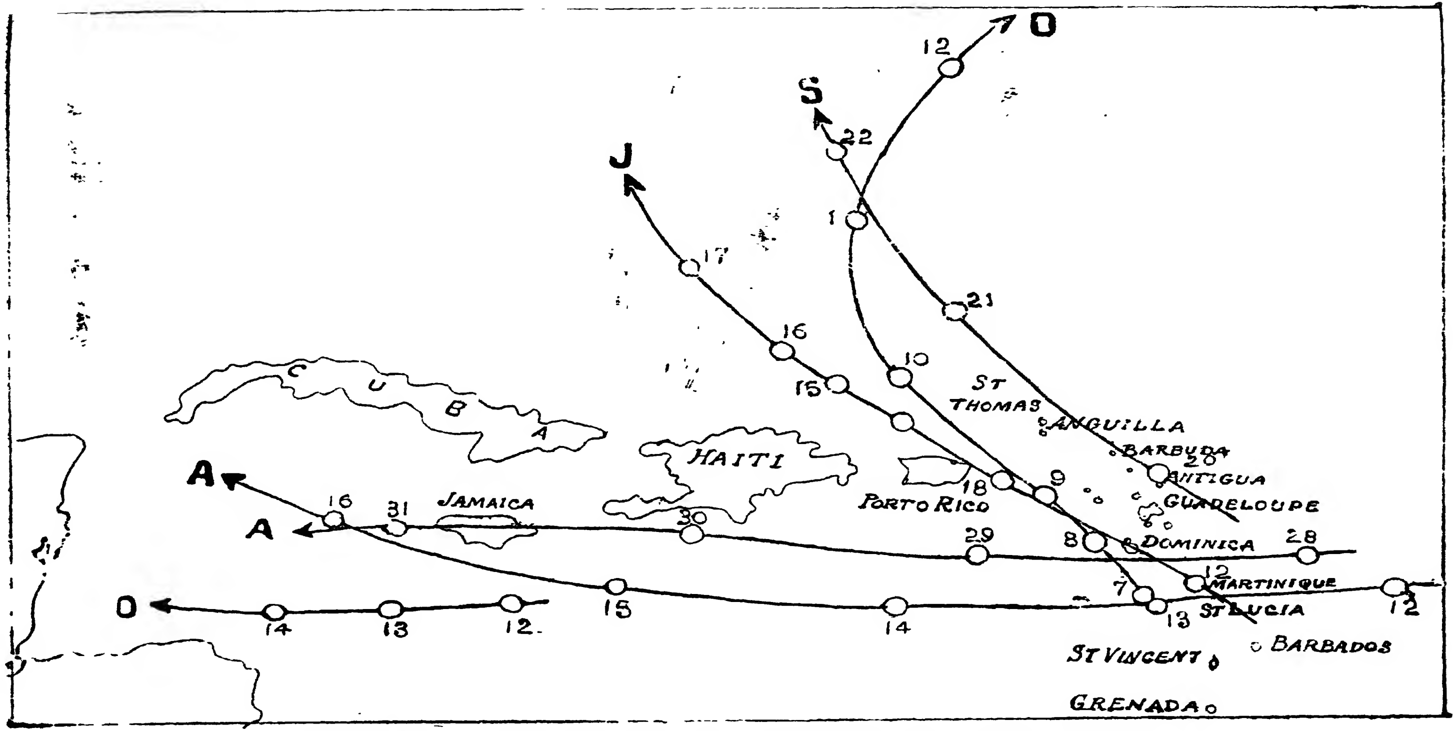
SEPTEMBER 22-30, 1915.—This storm had its origin to the west of the Windward Islands in approximately latitude 14° 30′ N., and longitude 63° W. It moved westward, passing south of Jamaica, and thence north-west through the Yucatan Channel, crossing the Gulf coast slightly west of New Orleans. The

lowest pressure recorded at that station was 28·11 inches, which is probably the lowest reading of a mercurial barometer ever observed in the United States. The report of lowest pressure observed at sea was given by the S.S. 'Almirante', in approximately latitude 15° 50′ N., longitude 77° 30′ W. The report contained information as follows: 'Barometer pumping between 27·50 and 27·60 inches.' The barometer was an aneroid with a correction of plus 0·01 inch. This is the lowest authentic reading reported in the West Indies or Caribbean Sea so far as known.

The hurricane was the most intense in history so far as our records show, and was of large area. The track was not usual for a storm of this month that passes from the Caribbean Sea through the Yucatan Channel.

OCTOBER 11-17, 1912.—This disturbance originated a short distance west of Jamaica in approximately latitude 18° N., longitude 80° W., and, after passing west-north-westward through the Yucatan Channel, struck the Texas coast at a point about equally distant from Corpus Christi and Brownsville. The disturbance was of only moderate intensity, and of small to moderate area.

The course of this disturbance was most unusual when compared to other October storms that passed through the Yucatan Channel. Only one previous storm of record followed a track at all similar to the 1912 storm, namely, that of 1887. The storms of 1886, 1887, and 1912 are the only tropical storms in the month of October that have struck the Gulf coast west of Mobile.



Hurricanes in 1916 affecting more particularly the Lesser Antilles.
J. July; A. August; S. September; O. October.
(Reproduced from Chart X,) *Monthly Weather Review* for December 1916. United States Department of Agriculture Weather Bureau.

HURRICANE CABLE CODE.

The following code is used in the West Indies by Agricultural Officers associated with the Imperial Department of Agriculture. The code is arranged so that a single 'word' of five figures shall convey adequate information as follows:—

The first figure signifies the direction of the wind
,, second ,, ,, ,, force ,, ,, ,,
,, third ,, ,, ,, height of the barometer
,, fourth ,, ,, ,, condition ,, ,, ,,
,, fifth ,, affords general remarks.

In the FIRST FIGURE:

1 signifies N	3 signifies E	5 signifies S	7 signifies W
2 ,, NE	4 ,, SE	6 ,, SW	8 ,, NW

In the SECOND FIGURE:

1 signifies Light air	5 signifies Strong gale
2 ,, Gentle breeze	6 ,, Violent gale
3 ,, Fresh breeze	7 ,, Dangerous gale
4 ,, Moderate gale	8 ,, Hurricane.

In the THIRD FIGURE:

1 signifies 30·1 inches	7 signifies 29·7 inches
0 ,, 30·0 inches	6 ,, 29·6 inches
9 ,, 29·9 inches	5 ,, 29·5 inches
8 ,, 29·8 inches	4 ,, 29·4 inches

In the FOURTH FIGURE:

1 signifies Barometer falling rapidly
2 ,, ,, falling slowly
3 ,, ,, stationary
4 ,, ,, rising slowly
5 ,, ,, rising rapidly.

In the FIFTH FIGURE:

1. signifies Weather stormy, but not threatening a hurricane
2. ,, Weather stormy, appears to threaten a hurricane.
3. ,, Serious apprehension is felt here.
4. ,, Storm centre appears to be approaching from the South.
5. ,, Storm centre appears to be approaching from the South-East.
6. ,, ,, ,, ,, ,, ,, from the East.
7. ,, Storm centre appears to be passing.
8. ,, Storm centre appears to have passed South of this place.
9. ,, Storm centre appears to have passed North of this place.

In the event of there being no observation to offer under any of the five heads 0 must be used. Five figures must be used in each case.

Example. A message 26916 would read as follows:—

Wind N.E., force violent gale, barometer 29·9 falling rapidly, storm centre appears to be approaching from the East.

INTERNAL BOLL DISEASE.

ADDENDUM.

In the last paragraph on page 223 of this issue the statement is made that the fungi of internal boll disease had not been found in other fruits. When this was already in print specimens of diseased tomatoes and cowpeas, received from the St. Vincent Experiment Station, were found to be heavily infested, the tomatoes with Species A and the cowpeas with Species D. In both cases the fruits were externally sound, but bore small scars such as would be produced by bug punctures, and had internal proliferations. On cutting open an affected tomato one or more sectors were found blackened, the placental tissue and the seeds infested with the fungus, and the juice charged with very numerous spores. In the case of the cowpeas, many seeds still succulent showed a brown dot on the testa with a circular fungus infestation on the cotyledon beneath. The subsequent growth of the fungus shrivels the cotyledons very severely by the time the seed should be ripe. Mr. Harland reports a total loss of crop on one plot of cowpeas, which according to the specimens sent as representative is due almost entirely to this affection.

W. N.

CORRIGENDA.

Page 170, the word 'Path' in Fig. 1 should be centred in space at the bottom of the figure instead of the top.
Page 183, line 1 of paragraph 2, for '12 per cent.' read *20 per cent.*
Page 188, line 16 from bottom, for 'modal' read *nodal.*
Page 222, line 4 from bottom, delete 'were'.

[Pages 167—273, issued 10th September, 1917.]

DISEASES OF SUGAR-CANE IN TROPICAL AND SUBTROPICAL AMERICA, ESPECIALLY THE WEST INDIES.

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INTRODUCTION.

It has seemed desirable to publish, in brief form, descriptions of common cane diseases and their causative fungi occurring in Tropical and Subtropical America. Such a publication should serve as a hand-book for those who are working on this subject and wish to carry out further investigations along the same line, and as a convenient book of reference for the planters who are interested in the diseases of cane, and who wish to know something of the nature of such diseases and methods for their control.

The bulk of the data in this paper was compiled by the senior author during his investigations on the subject. His observations were made during a four-year's residence in Porto

Rico, several years in Cuba, and in studies in Santo Domingo and in the Southern United States, besides various visits to many parts of Tropical America.

It has seemed especially desirable to make the records as complete as possible, since many of the fungi are of importance in considering plant quarantine regulations in different countries. For this reason the co-operation of various pathologists in the American Tropics was asked, and the results have been embodied as notes in this paper.

The paragraphs on the control of cane fungi were originally written for a paper on the cane fungi of Porto Rico, but inasmuch as control methods depend to a large extent on means which are at the disposal of every planter, and in fact are methods that any good planter should use in his general agricultural practice, it has seemed worth while repeating them here.

DISEASES CAUSED BY FUNGI OR BACTERIA.

Bacterium vascularum,—The Gumming Disease.
The Humid Gangrene or Polvillo.
Trichosphaeria Sacchari.
Gnomonia Iliau,—Stem Rot, or Iliau.
Sphaerella Sacchari.
Eriosphaeria Sacchari,—Red Leaf Spot.
Leptosphaeria Sacchari.
Thyridaria tarda.
Nectria laurentiana.
Ustilago Sacchari,—Smut.
Hypochnus Sacchari,—Thread Blight.
[*Odontia saccharicola.*]
[*Odontia sacchari.*]
Marasmius Sacchari,—Root Disease.
Marasmius stenophyllus,—Root Disease.
Schizophyllum alneum.
Laternea columnata.
Cytospora Sacchari.
(*Coniothyrium melasporum*), = Melanconium Sacchari.
(*Darluca melaspora*), = Melanconium Sacchari.
Diplodia cacaoicola.
Colletotrichum falcatum,—Red Rot.
Melanconium Sacchari,—Rind Fungus.
Melanconium saccharinum.
Cephalosporium Sacchari,—Wilt.
Thielaviopsis paradoxa,—Pine-apple Disease.
Cercospora longipes,—Brown Leaf-Spot.
Cercospora vaginae,—Red Spot of Leaf-sheath.
Cercospora Kopkei,—Yellow Leaf-Spot.
Helminthosporium Sacchari,—Eye Leaf-Spot.
Sclerotium Rolfsii,—Red Rot of Leaf-sheath.
Himantia stellifera.

BACTERIUM VASCULARUM, (Cobb) E. F. Sm.

The gumming disease of sugar-cane due to *Bacterium vascularum* was originally described from New South Wales. It was thoroughly studied by Dr. Erwin F. Smith, of Washington, and is believed by him to be the same as the gumming disease of

cane at Pernambuco, Brazil. This latter has not been thoroughly investigated, but a careful description of it, appearing in *The Sugar Cane* for 1894, answers so closely to the real gumming disease that little doubt remains as to their identity.

At one time this disease was so serious as to threaten the sugar industry in the province of Pernambuco. It attacked the Otaheite canes which were most commonly grown, and also the Imperial, a green striped cane, and the Creole, a small yellow cane.

The formation of a bright yellow gummy substance exuding from the ends of the fibres on cutting across the cane was characteristic. Affected cane showed an early drying up of the leaf tips ; the successive joints became smaller and smaller. Affected cane failed to ratoon. Juice of these canes was difficult to work up in the mill.

Dr. Smith says ([30]) * the most conspicuous signs of the gumming disease are dwarfing, etiolation, stripes on the leaves, reduction of sugar content, decay of the terminal bud, and the appearance in the fibrovascular bundles of a yellow slime and red stain. In early stages of the disease this slime is inconspicuous, but in later stages it is one of the most striking features of the disease, and frequently gives trouble in the sugar factories.

It has been definitely proven that the gumming disease of New South Wales is due to a bacterial organism, and presumably this Pernambuco disease has the same origin. The description of the organism is as follows :—

BACTERIUM VASCULARUM, (Cobb) E. F. Smith.

Parasitic on sugar-cane, clogging the vascular bundles with a bright yellow slime and forming cavities in the soft parenchyma ; frequently comes to the surface of the inner leaf-sheaths as a viscid slime. Surface colonies on + 6 standard nutrient agar pale-yellow, smooth, glistening, rather small, round, rather flat with sharp margins ; rods short, measuring on an average 0·4 × 1 microns when stained ; motile, single polar flagellum ; occasional very slight liquefaction of gelatine ; growth on potato cylinders good but not copious ; litmus milk is blued, no reduction of nitrates, no acids, no reduction of litmus, no gas. Group No. 21- $\frac{1}{3}$·3332523.

Satisfactory control of this disease is secured by selecting cuttings for planting from healthy canes, by using only those varieties most resistant to the disease, and by either abandoning badly infected soil or planting only absolutely resistant varieties.

THE HUMID GANGRENE, OR POLVILLO OF SUGAR-CANE IN ARGENTINA.

In 1895 Spegazzini ([28]) described a wet gangrene of the sugar-cane from the Province of Tucuman in Argentina. He ascribed the disease to bacteria, but did not thoroughly demonstrate this. His description of the trouble corresponds in many respects to the description of the gumming disease of cane, and it may be the same thing. It is difficult to tell if all the symptoms given by Spegazzini are peculiar to or characteristic of this disease, Polvillo, or if several diseases have been confused. The

*The numbers refer to the bibliography at the end of the paper.

symptoms given are as follows: the affected plant has a chlorotic aspect; and the leaves lose some of their rigidity and lustre, and bend down as if withered. On these plants certain leaf-blades bear long dead stripes, involving the entire thickness of the leaf tissue. These stripes are more abundant on the lower half of the leaf-blade, seldom reaching more than half the length of the blade. They are linear, narrow, of variable length, vivid red or more rarely violet or orange-coloured. The same stripes appear on the leaf-sheath, especially on the inside of the sheath. The inner faces of these leaf-sheaths also bear numerous red spots and a gummy exudate with a repugnant odour. Such leaf-sheaths are said to be thicker than normal, rigid, fragile, and breaking easily. The terminal bud is much inclined to rot. It comes out easily with a gentle pull from the leaf-sheaths which develop it, and then its basal part is found to be decomposed and yellowish or reddish, gummy, viscous, and transformed into a purulent paste with a strong odour. The decay extends sometimes downward through the central part of the mature cane stem, exceptionally even to the roots.

For control of this disease selection of cuttings only from healthy plants is recommended.

TRICHOSPHAERIA SACCHARI, Mass.

Said by Massee ([27]) to consist of ascigerous, stylosporous, macroconidial, and microconidial stages. The stylosporous or Melanconium stage is usually the one referred to in literature on this subject. The ascigerous stage has been found only by Massee, and the description of this was based upon two mature perithecia, on decayed cane from Barbados, and two immature perithecia found in flask cultures of the macroconidial stage (see *Thielaviopsis paradoxa*). No genetic connexion has been shown between the ascigerous stage of *Trichosphaeria sacchari* and the other forms, and the relation of the ascigerous stage to disease in cane has not been demonstrated. Nor has the relationship claimed by Massee to exist between the Melanconium and Thielaviopsis forms been confirmed. See *Melanconium sacchari*.

Perithecia broadly ovate, blackish brown, sparsely clothed with long, dark, rigid hairs; asci cylindrical: spores 8, hyaline, continuous, elliptic-oblong, 8-9 × 4 microns; aparaphysate.

GNOMONIA ILIAU, Lyon.

This fungus attacks the cane in all its earlier stages of growth. If the cane is attacked early and the season is favourable to the disease, many of the stalks remain small and often die, and many of those that live do not reach a height of more than one or 2 feet during the season. If the attack is not so severe or the season is more favourable to the cane, the stalks joint and attempt to outgrow the disease.

If the small stalks are examined, it will be found that all of the leaf-sheaths near the ground are firmly cemented together by the fungus mycelium. The sheaths are dead and also the blades of all the lower leaves. A few green leaves will be seen protruding above the dead mass of leaf sheaths at the base. If the sheaths are pulled apart a dense layer of white mycelium will be seen between them. The fungus often fruits on these

small stalks, though perhaps not so abundantly as on the larger ones. On jointed stalks that are diseased the lower leaf-sheaths are cemented closely to the stalk and the white mycelium is abundant between them, as well as within the tissues. Many of the blades of the lower leaves are dead, and the living leaves at the top often have a yellowish appearance and are close together, forming a loose tuft. The lower joints of a diseased stalk, underneath the dead leaf-sheaths, are shorter than normal ones and also are often much less in diameter than the joints above the diseased portion. The mycelium not only attacks the leaf-sheaths, but also enters the rind tissue so that often the sheaths are quite firmly cemented to the stalk itself. The fungus gradually works through the rind and in toward the centre of the stalk, though the progress inward is not rapid. The tissue is turned to a red colour as the disease passes through the centre. If a diseased stalk is cut across there is seen on the outside the layer of dried and shrunken leaf-sheaths, then the dead and slightly discoloured rind tissue, then a ring of red parenchyma, and finally on the inside a cylinder of uncoloured perfectly healthy parenchyma. The killing of the rind tissue weakens the stalks, and many of them fall or are blown over by the wind.

The Gnomonia fruits abundantly on the dead leaf-sheaths, and especially towards the fall of the year on the larger jointed stalks. Two stages of the fungus are found : the imperfect, which is placed in the genus Melanconium, and the ascogenous or Gnomonia stage. In Hawaii the Melanconium stage is more abundant, the other being rarely found, while in Louisiana the Gnomonia is the more common.

The imperfect stage either develops in the outer leaf sheaths or in the more deeply covered ones. It is not typical of the genus Melanconium, as instead of the spores being borne in open pustules or acervuli they are usually in well developed pycnidia. These pycnidia are imbedded in the leaf tissue, generally with but a pore at the top, though occasionally the apex may be prolonged into a well developed beak.

The perithecia develop very abundantly over the surface of the exposed dead leaf-sheaths and give the stalks a very characteristic appearance. The beaks extend for some distance from the surface and are very hard.

The disease due to *Gnomonia Iliau* and its imperfect stage is said to cause considerable damage in Hawaii and in Louisiana, particularly in the young cane.

Both Lyon [26] in Hawaii and Edgerton [9] carried out successful inoculation experiments to prove the relation between this fungus and the 'Iliau' of cane.

GNOMONIA ILIAU, Lyon.

Perithecia 325-480 × 240-310 microns in size with beak about 350-550 microns ; asci clavate, thin-walled, 60-80 × 14 microns with a well developed pore at apex ; spores 1-septate, hyaline, slightly curved, often slightly constricted at the septum.

Pycnidia 500-700 microns in diameter, and thin-walled ; spores dark brown, elliptical to oval, coarsely granular, 7-10 × 15-28 microns. Plate 1, Figs. 1-4, Plate 2, Fig. 2.

Hawaii and Louisiana.

SPHAERELLA SACCHARI, Speg. (4)

Spots none or pale, indeterminate; perithecia densely aggregated in series on the underside of the leaves, globose, 130-180 microns in diameter, glabrous, immersed, the papillate ostiole scarcely perforating the epidermis, dark olivaceous; asci cylindrical, 70 × 12, apex rounded and wide, base scarcely subattenuate, abruptly and minutely nodulose, pedicellate, 8 spored, aparaphysate; spores straight or obliquely distichous, ellipsoid, 16-20 × 5-6, 1-septate in the middle, not at all or only slightly constricted, hyaline smooth. Plate III, Fig. 3. Plate VII, Fig. 4.

Very abundant in cane leaves in Argentina, in Porto Rico and Cuba. On withering and dead portions of the leaves.

ERIOSPHAERIA SACCHARI, Went. (32)

This fungus is reported to cause deep red, yellow-bordered spots on the under side of the leaves.

Perithecia spherical, dark brown, 75 microns diameter, clothed, especially the upper part, with setae, dark-coloured, several celled, attaining a length of one half the height of the perithecia; ostiole cross-shaped; asci club-shaped, 8-spored, about 25 microns long; spores 1-septate, oval, 6 × 11 microns; paraphyses present. Plate III, Fig. 5.

Trinidad.

LEPTOSPHAERIA SACCHARI, Br. de Haan. (32)

This fungus is said to produce the ring spot appearance on green leaves so common in most cane countries.

The spots usually appear first as small purplish discolorations on the surface of the leaf. They increase in size, drying up at the centre as they expand at the margin. The ring consists of a purple or brownish band of varying depth, outside which there is sometimes a yellow areola losing itself in the green substance of the leaf.

The spots are irregularly elongated, and become eventually quite large. They run into one another quite frequently. Outside them the leaf eventually dries up, so that a feature of the disease is the premature withering of the leaf.

Microscopic examination of the tissues at the spots shows that they are permeated with slender hyaline threads which also spread on the surface and there give rise to conidial spores; van Breda de Haan has succeeded in infecting healthy leaves with the conidia.

At a later stage a second spore form appears, chiefly within the rings. Numerous black specks become visible, arranged in rows between the fine nerves of the leaf. These are the perithecia, the fruiting form usually associated with this disease.

Direct proof is lacking that these two spore forms belong to the same fungus, or that either is the cause of the disease. However, the perithecial form or Leptosphaeria is usually given as the cause of this disease.

[*Leptosphaeria Sacchari* is the most prevalent leaf disease of the sugar-cane in British Guiana, affecting seedling and other varieties alike. The quantity of the fungus occurring each

year is directly dependent on the climatic conditions. Late ripening of the cane is almost always accompanied by a large quantity of the fungus. C. K. B.]

Perithecia spherical, thin-walled, brown; 140 microns diameter, ascospores 3-septate, brownish, 20-24 × 5 microns; paraphyses present. Plate 3, Fig. 2.

Common in cane fields in most countries.

THYRIDARIA TARDA, Bancroft.

Perithecia in a single layer, with several small ones often superimposed, immersed in a black erumpent stroma, with minute ostiole; asci cylindrical-clavate with 8 spores, sessile, 90-100 × 12 microns; paraphyses 100-130 microns long, abundant, filiform; ascospores monostichous, oblong, fuliginous, triseptate, slightly constricted at the septa, 19-20 × 6-7 microns.

Reported by Bancroft to be the perfect stage of *Diplodia cacaoicola*, which see.

NECTRIA LAURENTIANA, Marchal. ([17])

Occurs on discoloured areas of the cane rind, usually near the nodes, on cane affected by moth borer or by another fungus.

Stroma somewhat broad, convex, superficial, 1-2 mm. diameter, seated on a hyaline, slender, cottony, evanescent, at first free, later confluent white parenchyma; perithecia densely caespitose, globose, or ovoid 250-350 microns diameter, strongly rugulose, even subsquamulate, ferruginous, glabrous, ostiole slightly dark, somewhat broad, membranaceous; asci 8-spored, oblong, cylindrical, at lower end subsessile, 60-70 × 7-8 microns; aparaphysate; spores in one series, oblong, equal-sided, straight, at bottom end obtuse acute, 2-celled, constricted in the middle, rarely the lower cell somewhat narrower; 12-13 × 4·5-5 microns, epispore rarely subasperulate.

Congo, Africa, and Porto Rico.

USTILAGO SACCHARI, Rabenhorst.

Sugar-cane affected by this fungus is recognized by possessing at the summit a long whip-like dusty black shoot, often several feet in length and much curved. This shoot is devoid of leaves, slender and flexible, and probably represents an abnormal floral shoot. In its earlier stages it is covered by a slimy white thin sheath which soon, however, ruptures, exposing a dense black dust consisting of the spores of the fungus.

From the upper portion of the affected cane, no secondary shoots arise, but from the lower part they are fairly abundant, being all in their turn attacked and prolonged into spore-containing organs. The tissues of the cane below the normal shoot contain the filaments of the smut fungus. These are found between the cells. Diseased canes are poor in sugar and worthless; the whole cane may, in fact, be destroyed.

Usually this disease appears in plants approaching maturity. It sometimes occurs, however, in plants only a few feet high, which suggests that the disease is carried through from the cane cuttings. Artificial infections in Java have given rise to diseased shoots in about a year.

Butler ([1]) reports that in India the disease does no great damage. Deer, however, reports the damage in Mauritius as considerable. Certain varieties seem to be more susceptible than others. These appear to be almost invariably slender varieties. In Java a case was reported where the disease appeared to spread from a wild cane, *Saccharum spontaneum*, to the sugar-cane. It also occurs on *S. Soltwedeli*, Kobus, *S. edulo*, Hask, *S. cylindricum*, and *S. Erianthi*, in Italy, Africa and Java. It also has been reported on sugar-cane in Trinidad, Mauritius, Natal, India and Queensland. [Present in British Guiana, but little damage has been attributed to it. C.K.B.]

Spores globose-subangulate, 8-10 microns, olive-brown, or rufescent; epispore smooth, thick. Plate 3, Fig. 1.

HYPOCHNUS SACCHARI, Speg.

Superficial, more or less widely effuse, (1-10 cm. diameter) emarginate, delicately membranous-arachnoid, white or scarcely sub-rosy, consisting of delicate hyphae densely interwoven, septate, hyaline; hymenium subvelutinous: basidia obclavate 20-35 × 5-8 microns at the upper end attenuate, somewhat curved, lower end obtuse, round, continuous, simple, rarely bifid, 1-spored, hyaline, spores ovate, 10-12 × 4-5 microns, hyaline, obtusely rounded at upper end, lower strongly acute, continuous, smooth, acrogenous.

Develops only on the growing part of cane diseased by 'Polvillo' (q.v.) Tucuman, Argentina.

Considered by Horne ([6]) to occur in Cuba also. Horne's fungus is a true Hypochnus with 4-spored basidia, and with large cystidia which are obclavate and marked with accretions on the walls. The fungus which Horne describes is very common in Porto Rico, causing a decay of the lower leaf-sheaths. Plate V, Fig. 3.

[ODONTIA SACCHARICOLA, Burt.]

[This fungus, which has been called the granular leaf-sheath fungus ([35]), is very common at the base of cane stalks, binding together very firmly the lower leaf-sheaths so as to make their removal difficult. Whether or not the fungus penetrates below ground to the extent of attacking the roots is a point which it has not yet been possible to investigate. The only visible damage is the rotting of the leaf-sheaths which are permeated by the mycelium. The fruiting areas occur as uniform thin white patches with a granular, somewhat powdery surface encircling the stalk from the ground level to a height of 8 inches or a foot.

The fungus is very commonly found on all varieties of cane, and occurs apparently independently of whether the stool is healthy or otherwise.

In all studies of root disease made heretofore, this form has been, beyond much doubt, confused with other forms, and the presence of root disease assumed where it occurred.

This form may easily be confused with the much less common species *O. sacchari*. To quote Dr. Burt ([33]), '*O. saccharicola* is thinner and is composed of shorter-celled hyphae which are not suberect, not nodose-septate and do not bear spores in the interior of the fructification. The stellate crystals are present abundantly

in all specimens . . . . . . and appear to be of aid for recognition of this species.'

[ODONTIA SACCHARICOLA, Burt.]

Fructification resupinate, effused, adnate, very thin, pulverulent, not cracked, whitish, drying cartridge-buff, the margin narrow and thinning out; granules minute but distinct, about 6-9 to a millimetre; in structure 30-50 microns thick, with the granules extending 45-60 microns more, composed of loosely and somewhat horizontally arranged, branched, short-celled hyphae 2-3 microns in diameter, not nodose-septate, not incrusted but having in the spaces between the hyphae numerous stellate crystals 4½-7½ microns in diameter from tip of ray to tip of opposite ray; cystidia hair-like, flexuous, not incrusted, septate, weak often collapsed, tapering upward to a sharp point, 1½-3 microns in diameter, protruding 8-18 microns, about 1-3 to a granule at the apex: basidia simple, cylindric-clavate, with 4 sterigmata reduced to mere points; basidiospore hyaline, even, 5½ × 2½ microns flattened on one side.

Fructifications 3-5 cm. broad, extending from the ground upward on sugar cane, in some cases 20 cm. or more and sometimes wholly surrounding the canes.

Exceedingly common in all parts of Porto Rico.

[ODONTIA SACCHARI, Burt.]

This species occurs on dead leaf-sheaths and at the base of living cane stalks in Porto Rico. It is not common. This same form has been referred to by Horne (6) in Cuba as *Peniophora* sp., and later as probably *Hypochnus sacchari*, Speg. The latter has also been suggested as the proper designation for the Porto Rican fungus, but Spegazzini's (57) description of the *Hypochnus* as the cause of a disease of the bud (*Cogollo*) rather effectively disposes of this possibility to say nothing of the characteristics of the fungus itself.

[ODONTIA SACCHARI, Burt.]

Fructification resupinate, effused--portions may be peeled from substratum when moistened—floccose, white, becoming ivory-yellow to pale olive-buff with age or in the herbarium, not cracked, the margin thinning out, floccose-reticulate under a lens; granules minute, sometimes so minute that they may be overlooked except in sectional preparations, crowded, about 8 to a millimetre; in structure 100-300 microns thick, with the granules extending 15-45 microns more, composed of suberect, branched, loosely interwoven, hyaline hyphae 3½-4 microns in diameter, occasionally nodose-septate, not incrusted, bearing singly along their sides in their middle region hyaline, cylindric, even spores 9-11 × 3-4 microns, basidia simple, with two sterigmata; basidiospores hyaline, even, subglobose, 3¾ × 3-3¾ microns, cystidia septate cylindric, more or less granule-incrusted, hyaline, 6-9 microns in diameter, protruding 20-60 microns, about 1-3 to a granule at the apex. Plate V, Fig. 3. J. A. S]

MARASMIUS SACCHARI, Wakker.

Symptoms. The earlier symptoms of this disease are the firm adhesion of the lower leaf-sheaths to the stalk as if glued by a white paste. When the leaf-sheaths are torn away, they break up and reveal a white membranous coating. The leaves adhere to each other and to the stalk, and the latter is not perceptibly

affected except in extreme cases. [In severe infestations the base of the cane, near its attachment, is commonly internally infested, as may be the new shoots attached to it. W.N.]

This adhesion of the lower leaf-sheaths is more conspicuous in those varieties of cane which normally shed the lower leaves, but its presence at all times can be readily ascertained by attempting to remove the trash. The fungus causing this root disease does not usually develop a conspicuous vegetative or mycelial growth on the outside of the outer leaf-sheaths. The white mould-like growth common at the base of the cane is due to other fungi. The root disease fungus does, however, under certain conditions develop small toadstools or mushrooms at the base of the cane and up on the leaf-sheaths as high as one or two feet from the ground.

The adhesion of the leaf-sheaths and even the development of the toadstools may be found on what appears to be normal cane. They indicate the presence at any rate of this disease-producing fungus. Under certain conditions such as poorly cultivated soil, worn out land, on stubble cane, or in the case of drought, cane with these fungi soon begins to look slightly dry, the leaves tend to curl a little, and the growth is checked so that an infected patch can often readily be told from one free from the fungus.

Young canes affected with the disease develop leaves more narrow, more tapering, and more pointed, and more upright, with a tendency to appear stiff.

Stubble cane is usually more affected than plant cane, as the fungus has had opportunity to gain a good foothold on the dormant stubble.

Cause. This root disease is due to the fungus, *Marasmius sacchari*, the fruiting bodies of which have been mentioned as appearing on the outside of the lower leaf-sheaths. These fruiting bodies are apparently very erratic in their occurrence; apparently erratic, but probably not really so For their development they require certain atmospheric conditions that do not always recur with regularity. In certain fields of Porto Rico the writer was never able to find fruiting bodies, although the vegetative or mycelial part was there. In other fields they occurred one year and not the next. In some fields they occurred in August one year and in December the next year. It is worthy of note that whenever they were found it was in the rainy season. Doubtless many planters have never seen them in their fields at all.

Fungus causing the disease.

MARASMIUS SACCHARI, Wakker.

Gregarious or fasciculate at base, variable, persistent, membranous; pileus white, widely campanulate, then dingy white, plane, or cup-shaped, 15mm. diameter; lamellae white, simple or bifurcate; stipe central, white, 15mm. long, apex tubiform, base villous: hyphae white; spores hyaline, continuous, irregularly oblong, attenuate at both ends, rounded, 16-20 × 4·5 microns. Plate IV.

The vegetative or mycelial stage of the fungus should be further described as consisting of minute white branching threads which grow luxuriantly in the roots and over the outside of the roots up the stem and in and over the lower leaf-sheaths. In wet weather they produce a gelatinous coating between the leaf-sheaths, and when this gelatinous substance dries it causes the adhesion of the sheaths to each other and to the stem. This character is peculiar to the fungus and is alone sufficient to identify it without the toadstool fruiting bodies. Other fungi produce white growths on the outside of the lower leaves, but they are powdery, or cottony, or feathery, and all lacking this paste-like adhesiveness caused by *M. sacchari.*

The white mycelial threads of the fungus penetrate and gradually rot the roots, thus slowly cutting off the water-supply of the plant and causing the appearance of drying out. The white mycelial threads under certain conditions come through the tissues of the leaf-sheaths to the outermost surface, and if the conditions there are favourable they may develop little white knots which ultimately grow into the small dingy-white umbrella-like toadstools or fructifications. These contain the numerous spores that serve to reproduce the fungus.

Methods of dispersal. These spores may blow about in the wind and thus serve to spread the fungus to other parts. As the fructifications are, however, uncommon, they are not the most ready means of dissemination. The mycelium itself in the soil and on the root may be broken off in portions and transported in soil, on implements, or on the feet of animals or labourers. Cane, the base of which is covered with the fungus, may be carried to other parts of the plantation for grinding or planting. The growth of the fungus directly through the soil itself is probably not important.

[The account given above corresponds in all respects with the characters of the disease as observed in Barbados and other of the Lesser Antilles. Widespread effects occur only in periods of insufficient rainfall, but there are always fields or patches to be met with in which the affection exists in an active form as a result of poor cultural conditions, from whatever cause arising.

Fields of plant cane infested as a consequence of low rainfall but otherwise in good condition have been seen to recover and give a good crop of ratoons when favourable weather supervened.

The cases in which, by reason of the absence of complications, the significance of *Marasmius sacchari* is most clearly seen, are those in which, as occasionally happens, plants only a few months old are attacked and severely injured or killed outright. The infestation of the roots and of the base of the shoots is then very obvious, and the fructifications of Marasmius develop in abundance on the infested shoots if sufficient rain occurs to maintain moist conditions for a few days. W.N.]

Infection experiments. Wakker in Java carried out successful infection experiments demonstrating that *M. sacchari* could injure cane, especially young cane. Howard ([15]) in Barbados also carried out successful experiments to this same end.

Geographical distribution. In Java it occurs particularly in the cane seed beds, but also occurs to some extent in older canes.

In Barbados ([29]) this fungus has been reported for some years, also from Trinidad ([11].) Sugar-cane root disease due to *Marasmius sacchari* has been reported from [all] of the Lesser Antilles [including Martinique and Guadeloupe. W.N.].

In Porto Rico *M. sacchari* has been definitely recorded for several years. Also in Cuba. Hawaii reports *M. sacchari* and the variety *Hawaiiensis*.

[In British Guiana the disease has been prevalent for the past ten years. It is called the dry disease. At first considered by Stockdale to be due to physiological conditions, it was shown by Bancroft in 1913 to be due to *M. sacchari*.

Adhesion of the leaf-sheaths may in some cases be caused by the mycelium of *Phallus aurantiacus*, one of the 'stinkhorns' commonly met with in cane fields. The purplish colour of the older mycelium and the presence of 'clamp-connexions' in abundance in the younger mycelium enable one to distinguish somewhat readily between the two fungi. 'Clamp connexions' in the mycelium of *M. sacchari* are either very scarce or altogether absent.

The symptoms of the disease in British Guiana are as follows:—

As far as is known, it usually appears in isolated stools or in a clump of stools scattered over a field. It is frequently particularly noticeable in the outskirts of a field, though it is by no means confined to these parts.

It appears in the form of a withering of the outer green leaves, which commences at the edges and proceeds towards the midrib. The central leaves are last affected. The top of the cane dries, and the cane dies.

Frequently an effort is made by the cane to produce new shoots, several 'eyes' below the top sprouting; this effect in fact frequently characterizes the disease.

The cane if cut open is found to be discoloured red. The red discoloration may appear in streaks or in thin lines.

The leaf-sheaths do not fall away readily from attacked canes, but tend to remain attached.

The old dry leaf bases are frequently matted together by a growth of white threads.

Many of the roots present a red or brownish colour, and are dead.

A growth of white threads is present in the soil at the base of the cane and is attached to the roots. This may be present in small quantity and may sometimes escape casual observation. C.K.B.]

[On some Jamaica estates, during drought, backward growth has been associated with marked development on the stools of ***Marasmius sacchari*** and ***Himantia stellifera***. S.F.A.]

MARASMIUS STENOPHYLLUS, Mont. (SEMIUSTUS, Mass.).

This is the common banana Marasmius, well known in the West Indies under the name *M. semiustus*. The fungus occurs in Cuba on sugar-cane as well as on bananas. Apparently the same species occurs on cane in Louisiana and Texas. The action of the species is the same as that of *M. sacchari*. The description is as follows :—

> Pileus thin, soft, fleshy, but tough and persistent, convex to irregularly expanded, umbilicate, becoming eccentric with age, gregarious to cespitose, 1-4 cm. broad ; surface minutely fibrillose to glabrous, radiate-rugose, hygrophanous, pale yellowish white to pale reddish-tan, margin concolorous, incurved when young, lamellae adnate with a slight collar, rare short decurrent, rather distant, broad, inserted. the long ones ventricose, white, interveined, often forking : spores ellipsoid, smooth, hyaline, about 7·9 × 5·6 microns : stipe tough, cylindric, tapering upward, usually curved, glabrous, white at the apex, pale-reddish below, whitish mycelial at the base, solid or spongy, at first central, often strongly eccentric with age, 1-4 cm. long, 1-2 mm. thick.

MARASMIUS PLICATUS, Wakker. (32) (10)

This fungus has been reported as the cause of a root disease of sugar-cane in Louisiana. Material collected by the writer is indistinguishable from that on banana and sugar-cane in Cuba. Moreover, it does not correspond with the original description of *M. plicatus*, Wakker, and therefore the writer has considered that *M. plicatus* of American authors should be referred to *M. stenophyllus* (see *Mycologia*, VIII, p. 115, 1916).

SCHIZOPHYLLUM ALNEUM, (L.) Schrr. (COMMUNE, Fries).

This fungus has been reported on cane in Pernambuco, in the British West Indies, British Guiana, Porto Rico and Cuba. It occurs very abundantly on diseased cane in Porto Rico, and occasionally appears to damage the standing cane. Also occurs in Santo Domingo, and the Southern United States. Pileus fan-shaped, very thin, white and grey, downy, often lobed, 2-5 cm. broad, gills pale brown with a purple tinge, split portions and edge of gills revolute ; spores dingy, 4-6 × 2-3 microns.

LATERNEA COLUMNATA. (Bosc.) Ness.

This fungus is common in the cane fields of Western Florida and of Louisiana. Its rhizomorphs are attached to the cane roots and stubble, and usually this association occurs only when the cane is in a decidedly diseased condition. Whether the fungus is the cause of this condition or not has not been decided.

CYTOSPORA SACCHARI, Butler.

This fungus is reported by Butler (1) from British India as causing eruptions on the rind. He considers the fungus as apparently a parasite. In the case of one stool examined, the stem at one end of the upper internodes was affected and the fungus was present on the leaf-sheath as well.

The same fungus also occurs in Porto Rico. It has been found on several varieties of cane, but never general in the field. It causes a distinct disease which is characterized by the leaf-sheaths drying but remaining on the stalk ; in the case of the coloured stalks they become more or less blanched, and eventually

the entire stalk is killed. It attacks and kills not only the small shoots in large stools but also the large nearly mature or mature stalks. The leaf sheaths become literally covered with the projections of the pycnidia. The fructifications also occur on the stalks of fallen cane and on cane cuttings where they cause eruptions of the rind. The general appearance of the fungus is much like that of *Gnomonia iliau.* Butler's description is as follows :—

> Stromata verruciform, arranged in a series, subcutaneous erumpent, plurilocular, black, ostiole elongate, single, rarely furnished with two; spores minute, cylindrical curved, obtuse at both ends, 3·5 × 1-1·5 microns; basidia branching, septate, 12-18 microns. Plate III, Fig. 4.

In the Porto Rican material the spores are not so distinctly curved as in that of Butler. It is, however, probably the same.

CONIOTHYRIUM MELASPORUM.

In 1895 Saccardo changed the name of *Darluca melaspora* to *Coniothyrium melasporum.* In the same year Prillieux and Delacroix studied material from Mauritius which showed the same black erumpent fungus on the cane as did Darluca. They identified their fungus to be identical with *Darluca melaspora.* Their drawings answered well to *Melanconium sacchari.*

DARLUCA MELASPORA, Berk. in Litt.

In 1898 Cook published a description of one of Berkeley's fungi as follows :—

> Pustulis prominulis, nigrus, sporis oblongis binucleatis, cirrhis nigris, 0·015 × 0·115 mm. From sugar-cane in Australia.

Evidently synonymous with *Coniothyrium melasporum* and *Melanconium sacchari.*

DIPLODIA CACAOICOLA, P. Henn, LASIODIPLODIA THEOBROMAE, Griff. et Maubl. [13]

This fungus occurs on canes that have as a rule been injured by other fungi or by insects. Affected canes are dried and generally show longitudinal wrinkles. The rind is raised into numbers of little elongated blisters which are arranged in rows following each other closely in the row. These blisters soon burst and in moist weather exude strings of spores which at first may be white but later turn dark. The resulting appearance is not unlike that of *Melanconium sacchari.*

> Pycnidia scattered, in the cortex, innate, black; spores ellipsoid, oblong or subovoid, 1-septate, obtuse at both ends, loculi 1-guttate, sooty black, 18-22 × 12-14 microns.

> British India, Barbados, Trinidad, Porto Rico, Santo Domingo and Cuba.

COLLETOTRICHUM FALCATUM, Went.

This fungus is the cause of the red rot disease of the cane stalk. The diseased plants do not show any special outward indications, at any rate so long as they are not severely affected.

At a later stage, however, the plant dies away, as is evidenced by the leaves becoming prematurely yellow and withered. The diseased appearance, however, shows itself plainly on cutting the stalks longitudinally, and it is then seen that in some cases one single joint, in other cases several joints, are attacked; in the latter instance, these joints are for the most part separated from one another, so that two consecutive joints are comparatively seldom found affected. The disease shows itself in the shape of a red colouration of the interior of the joint, accompanied by an acid odour. The red colour is commonly unequally distributed, being darker in one place than in another, and when, in addition, the occurrence of peculiar white spots is also remarked, the stalks appear, on being cut, to be blotched all over; the white patches are especially distinctive as regards the 'red smut'. The rind is unaffected by this fungus.

Howard working in Barbados on this same fungus maintained that it was the cause of the West Indian 'rind disease'. He apparently overlooked the fact that the rind disease was commonly recognized by the presence of numerous eruptions of the rind from which oozed black filaments, a condition not produced by nor connected with the fungus *Colletotrichum falcatum*. Howard arrived at his conclusion by securing successful inoculations with the Colletotrichum and failing to obtain infection with *Melanconium sacchari*. His work demonstrated that the former was a parasite and produced symptoms similar to the fungus in Java. [At the time when Howard was working, the name rind disease was in general use for the affection which eventually drove the Bourbon cane out of cultivation. Later experience supports his conclusion that Colletotrichum was the principal factor in this. The universal and conspicuous secondary infestation of the diseased canes with Melanconium explains the popular name. The later restriction of the term to the affection actually caused by Melanconium is largely an outcome of Howard's work. The symptoms of this affection are not those which Howard described. W.N.]

Edgerton (⁴) has gone one step farther than the others. Ordinarily, at least, in the incipient stages, the presence of the red rot cannot be determined by external examination. It is only on badly injured and dried portions of the stem that the fungus fruits, or on old dead stems. Edgerton, however, found that the canes in Louisiana often had red streaks on the midribs of the leaves. These began as smooth spots but often extended to considerable length, but did not extend into the adjacent leaf tissues. He succeeded in isolating *C. falcatum* from these red spots and also in reinfecting healthy plants and artificially producing the red spots. Edgerton believed that by the presence of these red stripes of the leaves he could determine the presence of *C. falcatum* in a field in its early stages. Stevens of Florida made isolations of fungi from the red stripe of cane and confirmed Edgerton's findings that *C. falcatum* was present. The writer in Porto Rico rarely was able to find this fungus in the red stripes but almost invariably other species of Colletotrichum were present. Butler reported *C. falcatum* causing red stripes on the

midribs of the leaves, but he did not state that it was an early symptom of red rot. Went's description of the fungus follows :—

> Setae in a series or arranged in a cuspidate pseudo-conceptacle, 100 × 200 × 4 microns, smoky, above paler ; conidia falcate 25 × 4 microns, produced at the base of the setae ; basidia ovoid 20 × 8, hyaline or dark. Plate VII, Fig. 1.

Geographical distribution. First described by Went from Java. In British India considerable work has been done on this fungus. Butler reported it as being transmitted through cuttings. Reported from Mauritius. Howard in Barbados investigated the fungus and proclaimed it the cause of the widespread rind disease. Material from Jamaica was examined by Massee, who identified *C. falcatum* and reported it as causing a root disease. However, no field or inoculation work was done to prove this. The writer has investigated it in Porto Rico, Santo Domingo, Cuba, and the Southern United States. In Porto Rico the virulence of the fungus is more or less connected with the variety of the cane, and with weather conditions. In Santo Domingo it is present but appears to do no appreciable harm. It occurs in Florida, Georgia, Louisiana, and Texas, chiefly in the form of the red stripes, but has also been reported by Edgerton as causing trouble in the bedded cane. Investigations by the writer in Georgia have shown that it causes considerable loss in bedded cane. Lewton-Brain has reported the fungus present in Hawaii.

Infection experiments. Went, Butler, Howard, Edgerton, have done most in the way of inoculations. Many were successful and some were not. They have been sufficient to show that under certain conditions the fungus is an active parasite. It is equally true also, that under some common conditions the fungus will not develop.

Loss from disease. Probably the greatest loss from the disease has been reported from India, but at times it has certainly been severe in the West Indies. [The arrest of the epidemic of this disease in the Lesser Antilles by the adoption of resistent varieties affords one of the most striking instances of success from this method of control. W. N.]

MELANCONIUM SACCHARI, Mass.

This fungus is the one commonly associated with the rind disease of the sugar-cane. No one has made successful infection experiments to prove this. In view of extensive field studies, they hardly seem necessary.

The fungus appears on the stalks of cane as fine black threads emerging from the rind. In an earlier stage the rind may be covered with numerous slight elevations or blisters. These break open, and in moist weather the fruiting mass emerges as threads, or in dry weather it appears as slightly conical projections. The fungus usually fruits very abundantly so that the entire rind in an affected area is killed. This is itself sufficient to account for withering of the leaves and final death of the plant, without the aid of any other fungus.

The fungus occurs chiefly on the rind, but is also found commonly on the base of the leaf-sheaths.

The fungus commonly attacks overripe cane, never uninjured green cane. It sometimes develops in the cuttings, destroying them completely. It is a fact, moreover, that large, healthy-looking mature canes, apparently uninjured, often quickly succumb to some disease, and this is the only fungus found present. Such stalks first become water-soaked in the interior, they turn sour and dingy-coloured inside, and eventually the pustules of the fungus develop under the rind, and the whole stalk dies. This commonly occurs on a few stalks in a stool and occasionally affects a whole field.

The virulence of the fungus or the damage caused by it varies a great deal in the different countries according to different conditions, while it appears to be present in almost all cane districts.

MELANCONIUM SACCHARI, Mass.

Conidia produced in pycnidia formed under the epidermis, unicellular, pale brown, cylindrical, straight or slightly curved, 14-15 × 3·5-4 microns. Plate II, Fig 1.

Geographical distribution :—

Java. Reported by Went, but he also reports another spore form. Considered by him to be strictly a saprophyte. He also refers to a black spherical spore form and to chlamydospores.

Australia. Reported by Cobb under the name *Strumella sacchari.*

Mauritius. Reported by Prillieux and Delacroix under the name *Coniothyrium melasporum.*

Natal. Reported by Fuller under name *Strumella sacchari.*

British West Indies. Reported many times from Barbados, Trinidad, British Guiana, and the smaller islands. Reported from Jamaica by Cockerell under the name *Trullula sacchari*, E & E, also as *Melanconium sacchari* by Fawcett. [*Melanconium sacchari* has long been known as a cane disease in British Guiana. The damage attributable to it in different years varies greatly. It appears in most cases, though not always, to be most prevalent at seasons when the small moth borer (Diatraea) is most abundant. C. K. B.]

Porto Rico. Reported by the Mayaguez Experiment Station and by the Sugar Planters' Experiment Station as causing serious injury under certain conditions.

Santo Domingo. Reported by the writer ([18]) as common but apparently harmless.

Cuba. Common and of considerable importance.

Southern United States. Common but not causing serious injury.

Hawaii. Common, and especially injurious on cane attacked by the leaf hopper.

[*Jamaica.* Rind disease accompanied by moth borer and pin borer injury, causes loss at times in ripe or overripe canes. S.F.A.]

Nomenclature. This fungus has been reported under different names, and as having different stages. It was first described by Cooke in 1878 from a description by Berkeley of material from Australia. The name *Strumella sacchari* was given to the fungus. In 1891 Cooke described the same fungus from Queensland under the name *Darluca melaspora.* In 1892 Ellis and Everhart described this fungus under the name *Trullula sacchari* from Jamaica. In 1893 Massee described this fungus as the Melanconium stage of *Trichosphaeria sacchari* but without giving substantial proof of the connexion. In 1895 Saccardo changed the name of *Darluca melaspora* to *Coniothyrium melasporum.* However, the genus Melanconium is the proper place for the fungus, and it has but one definitely proven stage, which bears the name *Melanconium Sacchari*, Massee.

Conditions of occurrence of the fungus. This fungus may be found at the base of the leaf-sheaths of cane over nine or ten months of age not uncommonly, and also on badly injured or diseased cane stalks. On nearly mature and overripe cane the fungus attacks large, apparently uninjured stalks and more or less destroys them. This differs with variety, with vigour of plant, and climatic condition. To illustrate: cane badly infested with borer in Porto Rico may completely rot away if also affected with the rind fungus, *Melanconium sacchari*; but borer-infected cane in Santo Domingo or in Louisiana is rarely or never rotted throughout by the action of the rind fungus. Again, if the tops are cut from mature or nearly mature cane in Porto Rico they frequently become infected and rot throughout with the rind fungus. If the tops are removed from cane of the same age in Santo Domingo, the cut joint often becomes infected, but the fungus seldom passes down into the other joints. This variability in the fungus or in the conditions under which it occurs accounts for the fact that in certain countries it is considered a harmless saprophyte and in others at times an active parasite.

MELANCONIUM SACCHARINUM, Penz and Sacc.

Acervuli hypophyllous, gregarious, arranged serially, oblong, 1 mm. long, 0·15 mm wide, black, hysteroid erumpent; conidia large, globose-compressed, 24 microns × 14, black, smooth, borne on slender, filiform hyphae.

Java, Porto Rico, Southern United States, Cuba.

CEPHALOSPORIUM SACCHARI, Butler. [3]

This fungus was first described as causing injury to cane in British India. It has since been reported from Barbados and Nevis. [36]

Except in cases of severe infections there is little seen of this disease until the canes are half grown. At this period, affected canes lag in growth. and stunted, single stools, or patches of varying size, may soon be observed scattered through the fields in which the disease is prevalent. From this on until the time of harvest, withering of individual canes, or even of whole stools occurs. The leaves dry up as if insufficiently supplied with

water, followed by the stems, which become light and hollow. If the cane be split longitudinally when the leaves are first observed to wither, a characteristic discoloration of the pith may be observed. Instead of the bright red patches and streaks, broken by transversely expanded white areas, seen in the red rot disease, there is a diffuse purple or dirty red discoloration, in which brighter red, vertical lines mark the position of the bundles. The stem is infested throughout the reddened portion by a fungus whose hyphae ramify through the cells in all directions. In the hollow which invariably forms in the pith of infected internodes at a late stage in the disease, there is usually a copious greyish-white, fluffy growth of hyphae, similar to those found in the tissue, and bearing great numbers of conidia.

CEPHALOSPORIUM SACCHARI, Butler.

Effuse, white, hyphae creeping, sparsely septate, 3-5 microns in diameter; conidiophores continuous, simply furcate or verticillate, above obtuse, at the middle or toward the base widened, 6-30 microns long, 3-4 wide; conidia numerous, arising in succession at the apex of the branches and collected in a head but easily separating, hyaline, ovoid or oblong ellipsoid, continuous, 4-12 x 2-3 microns. Plate VI, Fig. 4

[Successful inoculation experiments with the Barbados fungus are reported by J. S. Dash ([31]) but the resulting infection was limited in extent except where the cane was otherwise injured. This corresponds with the observation that serious effects were confined to canes whose normal growth had been interfered with by the wrenching action of strong winds or the presence in the stool of *Marasmius Sacchari.* The outbreak in Barbados in 1915 was rather widespread, but restricted to a short period. No direct comparison of the West Indian with the Indian fungus has been made, but the close similarity of the two justifies careful attention to all such affected canes. W. N.]

THIELAVIOPSIS PARADOXA, (DeSeynes) Von Hohnel.

This fungus was first described in 1886 by DeSeynes as occurring on pine-apple and designated as *Sporoschisma paradoxum.* In 1892 Saccardo referred it to *Chalara paradoxa,* (DeSeynes) Sacc. Went in 1893 described a fungus causing serious loss to the sugar-cane growers of Java and named it *Thielaviopsis ethaceticus.* Von Hohnel in 1904 called attention to the identity of the two, and named it *Thielaviopsis paradoxa.*

The fungus rarely occurs in standing cane but is common and ofttimes very destructive in cane cuttings. Cuttings attacked by this fungus become blackened throughout the centre. The development varies with different varieties of cane and different conditions. In the soft thick canes it is often simply a blackening of the centre. In thinner and harder canes there is usually first a bright-red discoloration sometimes mixed with distinct yellow. The reddened centre of the cutting becomes darker and ultimately blackens with the development of the spores. The progress of the fungus is often so rapid as to preclude the successful germination of the eyes. Occasionally, however, the eyes germinate

and succeed in developing roots, before being attacked by the fungus. The fungus is not known to injure the growing shoots.

The fungus appeared to Went to represent a new genus and species as follows :—

Characters of genus :

Sterile hyphae hyaline or pale fuscous, septate. Fertile hyphae septate, not branching. Macroconidia ovate, fuscous, catenulate, at length separating. Microconidia cylindrical or bacillar, hyaline, borne in chains in the interior of the hyphae and at length escaping from the apex.

Characters of species :

Macroconidia 16-9 10-12 microns : Microconidia 10-15 × 3·5-5, within hyphae 100-200 microns long. Plate VI, Fig. 1.

Went explains and illustrates very clearly the formation of both macroconidia and microconidia ; that the former arise by a septation of the hyphae, and the latter by a septation within the hyphae ; also that the macroconidia are dark and the others hyaline. DeSeynes placed his pine-apple fungus in the genus Sporoschisma, which shows either that he did not know his fungus perfectly, or that he had one different from Went's, for Sporoschisma has dark, 1-septate spores borne internally. Saccardo, however, was evidently satisfied as to the nature of the fungus, for he removed it from Sporoschisma to Chalara. This places it in a genus which has hyaline spores borne internally. Von Hohnel evidently obtained information about the fungus of DeSeynes, for he believed it identical with *Thielaviopsis ethaceticus*, that is, that it had dark externally borne macroconidia, and hyaline internally borne microconidia.

In 1893 Massee described *Trichosphaeria Sacchari* and connected with it *Melanconium Sacchari* and a macro- and a microconidial stage. Massee distinctly describes and illustrates both the macro- and microconidia as being internally borne, and both spore forms distinctly coloured.

Notwithstanding these differences, Went has stated that the two spore forms of Massee are possibly identical with his two, and subsequent writers have agreed upon this.

So far as the material of Porto Rico is concerned, that found naturally affecting pine-apples is the same as that on cane. Moreover, the macroconidia, while under low power appearing to be borne externally, under high power can be definitely seen to emerge from the hyphae. As far as the microconidia are concerned, they are hyaline at first and may later turn decidedly brown. Petch published an excellent paper based on his work in Ceylon, and correlates the descriptions of the various authors, confirming the writer's findings in Porto Rico. In accordance with this, the characterization of the genus Thielaviopsis should be modified. That portion relating to macroconidia should read 'macroconidia ovate, fuscous, catenulate, at length separating, formed by extrusion of the protoplasm of the sporophore and the successive cutting off of portions.' That part relating to microconidia should read 'microconidia more or less cylindrical, hyaline, or at length becoming brown, formed in the interior of the sporophore, emerging from the apex in a chain, and at length separating.'

[The method of formation of the macroconidia described by Johnston has not been observed by me in Jamaica in cultures from cane, coco-nut palm, and bananas. The development has been seen to be acrogenous as illustrated by Went, Cobb, Larsen and others; the end portion of the sporophore swells, becomes oval, and a transverse septum forms at the base of the enlargement; it looks, at times, as if this septum does not split, so that the spore appears to retain the whole of it, leaving the end of the sporophore open, and pressing on the base of the spore; this appearance may be accompanied by a withdrawal of the plasma from the end of the sporophore, leaving a short clear region bounded by the cell-wall. These appearances may have caused Johnston to infer extrusion. In reality, no doubt, the septum does always split though the sporophore portion may be very thin; if the plasma contracts it would seem to form a new septum before the apex of the sporophore again swells up. Something very similar was observed recently in the formation of conidia in a powdery mildew on mango flowers.

It is curious that Went does not refer to the frequent browning and oval shape of microconidia in his diagnosis of the genus ([32]). His original account was published in the *Archives of the Java Sugar Industry* in 1893. Kruger mentions the browning and oval shape (*Das Zuckerrohr*, 1899, p. 414) and furnishes an illustration, after Went (P. 417 D.), showing such conidia within and without a sporophore.

Strains of this fungus isolated from cane cuttings, spots on the heart-leaves of the coco-nut and banana bulbs do not differ in growth. A variety frequently observed as a saprophyte on decaying coco-nut tissue develops dark coremia in nature and in culture: in all other respects (growth, conidia) it resembles the above strains (see footnote, p. 120, *Bull. Dept. Agric.*, Jamaica, Vol. 2, No. 6, 1913).

A form was recently isolated from the sap-wood of a pimento tree in which the mode of formation, size, and colour of the micro- and macroconidia agreed with *Rostrella coffeae*, Zimm.; minute immature black perithecia (?) appeared on the mycelium in culture suggestive of Thielavia in development. S.F.A.]

Geographical distribution of the fungus. Java, the British West Indies, Porto Rico, Santo Domingo, Louisiana, and Hawaii have this fungus on cane according to reports. [Common in British Guiana. C.K.B.] It has also been reported on the endosperm of the coco-nut in Vienna, as a cause of the stem-bleeding disease of the coco-nut palm in Ceylon and in Porto Rico, and as a cause of diseases of pine-apples in Porto Rico and Hawaii.

Conditions favourable to the fungus. Cane cuttings that are subjected to a period of drought are more liable to the disease caused by this fungus than are cuttings under normal circumstances.

CERCOSPORA LONGIPES, Butler.

The cause of the brown leaf-spot. The first appearance of the disease is characterized by the outbreak of narrow, oval spots about [illegible]-inch in length and of a reddish [illegible]

both surfaces of the leaf. These increase in size, and a brown centre becomes clearly evident. At the same time the tissue around the spot becomes discoloured and a well-marked yellow areola may be formed. Butler's description of the fungus follows :—

> In spots which are elongated, on both sides of the leaf, often confluent, at first red, then bordered by yellow and by brown bands ; hyphae collected in gregarious heads, generally hypophyllous, flexuous, brown, above geniculate or denticulate, 100-200 x 4 microns ; conidia obclavate, attenuate above, straight or slightly curved, 4-6 septate, 40-80 x 5 microns, hyaline.

Very common, especially on the thin canes, in India. Also reported from Trinidad and Porto Rico. Plate VI, Fig. 3.

CERCOSPORA VAGINAE, Kr.

The cause of the red spot disease of the leaf-sheath. Produces brick-red spots usually toward the base of the sheath, which become an inch or more in diameter. Eventually the centre of the spot darkens and becomes black with the growth and fructification of the fungus.

The spores are usually two or few-celled, and have two forms, those appearing on the outside of the leaf-sheath differing in most cases from those appearing on the inside by their crooked form. They are 19·6-42 x 7 microns. Plate VI, Fig. 2.

Reported from Java, Trinidad, [British Guiana, C.K.B.] Porto Rico, Santo Domingo, Cuba, Jamaica, and the Southern United States.

It is very common on certain canes [e.g. D. 95, C K.B.] and rare on others.

HELMINTHOSPORIUM SACCHARI, Butl. (?).

The cause of the eye spot disease of sugar-cane. The infected leaf first shows small red spots, which spread rapidly, chiefly in a longitudinal direction, and especially toward the tip of the leaf, and may run together to form long streaks. The centre of the spot soon changes to a dirty straw colour, around which the margin remains red for a time and then changes to dark brown. Butler's description is as follows :—

> In spots amphigenous, elongated, at first red, then bordered with either a straw-coloured band or a ferruginous one, 3-25 x 2-6mm., heads small black ; hyphae fertile, simple, 3-10 septate, geniculate, olive-brown, apex paler, 100 190 x 5·5-7·5 ; conidia acrogenous, cylindrical or oblong-elliptical, round at both ends, 3-10 septate, very widely tunicate, olive-brown, 35-60 x 8·5-12 microns. Plate VII, Fig. 3.

Probably identical with *Cercospora sacchari*, Br. de Haan, which from illustrations does not appear to be a Cercospora but an Helminthosporium. This fungus is reported from Java, Jamaica, Trinidad, and Hawaii. Apparently the same fungus occurs in Porto Rico and Cuba but is reported as Helminthosporium.

SCLEROTIUM ROLFSII, Sacc.

This fungus causes the disease known as red rot of the leaf-sheath. It is characterized by an orange-red discoloration of the

green sheath and the presence of small, more or less red-brown sclerotia. In the initial stages the white feathery mycelium ascends the stalk from the ground, and for the most part develops between the sheaths and the stalk, while the sclerotia are formed along the margin of the sheath or on the outside. The fungus may ascend to a considerable height, but its chief activity is confined to the region toward the base. In severe cases the nodes are attacked and the rind is rotted away in small pitted areas. In certain regions the damage appears to be chiefly that of retarding the development of the shoots. In other regions it attacks the larger canes and causes considerable injury.

Sclerotium Rolfsii is reported from the Southern United States as common on cane and causing considerable damage to it in Georgia, also occurring on many other crops to a serious extent. It is reported as causing considerable injury to cane in St. Croix; it is very abundant but seldom injurious in Porto Rico, and occurs in Cuba, Jamaica, and Barbados. In all probability this is the fungus referred to by Wakker and Went as causing the red rot of the leaf-sheath in Java.

The sclerotia are minute, at first white, then yellow, and turning to red brown and finally a dark brown.

HIMANTIA STELLIFERA, Johnston ([35]).

This fungus causes a decay of the roots and of the lower leaf-sheaths. Its presence is made evident by the feather-like white mycelium apparent on the outside of the leaf-sheath and between the leaf-sheath and the stalk. This fungus is extremely common on cane in Porto Rico, and likewise on many of the ordinary pasture grasses, so that its presence is of considerable importance in considering allowing sugar-cane land to lie fallow, and in planning for the rotation of crops. It was reported first from Hawaii by Lewton-Brain ([24a]) and later referred to by Cobb ([5]) as the 'stellate crystal fungus.' [Occurs in Jamaica. S.F.A.] The description is as follows:—

> Mycelium cobwebby, or somewhat dendritic, white, ascending the lower leaf-sheaths and within the roots, hyphae with clamp-connexions, and bearing on short side branches stellate crystals of calcium oxalate. No fruiting bodies known. Plate V, Fig. 4.

DISEASES NOT PARASITIC, OR THE CAUSE OF WHICH HAS NOT DEFINITELY BEEN PROVEN.

Yellow stripe disease.
Top rot.
Sereh.
Mottling disease.
Wither-tip.
Chlorosis.

YELLOW STRIPE DISEASE.

Characterized by yellow stripes on the leaf-blade and stem, with more or less the appearance of chlorosis. Cause not ascertained. Reported to increase in severity in successive ratoons. Severity greater or less in different varieties, therefore selection of seed recommended for control. Shows some similarity in

appearance with the leaf-splitting disease of Cobb, which was said to be due to *Mycosphaerella striatiformans*. Porto Rico. Said to be the same as the disease in Cuba.

TOP ROT.

Characterized by a soft rot of the inner leaves of the cane top. Variously reported as occurring chiefly on young canes and chiefly on mature cane. Cause unknown. Decayed condition often associated with borer injury, but not always. In Porto Rico never in the form of an epidemic but in isolated, cases; sometimes in young cane but usually in mature canes; sometimes no insect injury can be seen. In Texas one field of seven- or eight-months cane had many stalks dwarfed and with rotted tops, usually free from borer.

Reported in Java, Mauritius, Demerara, Porto Rico, Cuba. and Texas.

SEREH.

A disease of cane in Java; it has been extensively studied. and many theories are extant as to its cause, but this is not yet determined. In its most typical form the affected cane most resembles bunches of lemon grass (*Andropogon schoenanthus*), the Javanese name for which is 'Sereh', hence the application to the diseased cane.

Symptoms of disease ascribed to this form are numerous, as follows :—

1. A shortening of the internodes, thus bringing the leaves closer together in a fan-shaped affair.

2. The leaves are much smaller than normal ones and remain on the plant, not falling off as is customary. The leaf-blade is yellow-striped and dies in severe attacks.

3. The leaf-blades open in succession on the short internodes abnormally early, and stand out widespread.

4. The germination of the shoot and the root eyes on sereh-diseased cane at the nodes just above the ground. This appearance varies a great deal on sugar-cane due to different causes (flowering, borer, layering, etc.).

5. A strong dwarfing of the stem.

6. A weak and a quick development of the roots. The root system of a plant badly affected with sereh disease is either more or less dead or completely developed. Frequently the roots are much branched.

7. Failure of flower formation.

8. Anatomical changes, especially disintegration of the stem tissues.

9. A quick decay of the cuttings of sereh-diseased cane in the ground with red staining.

Few or all of these symptoms may be present in diseased cane. The cause of the disease has been ascribed to many things, as follows :—

1. Unfavourable soil.

2. Degeneration or atavism.

3. Abnormal weather conditions, especially great dryness or too much rain.

4. Incorrect fertilizing

5. Incorrect planting, and ignorant cultivation, especially deep planting, high hilling, early or late planting.

6. Dearth of water through the death of the roots and consequently gum or resin formation in the stem, or a stoppage of the bundles by the secretion which forms in the bundle.

7. Animal or plant parasites.

Among the parasites are described the following :—

1. Root parasites :

a. *Heterodera radicicola*, Mull. acc. Treub.

b. *Tylenchus sacchari*, Sollw. acc. Soltwedel.

2. Stem parasites and bacteria, acc. Kruger.

3. Root, stem, and leaf parasites and *Hypocrea sacchari*.

The disease has been reported besides in Java, also in Malacca, Borneo, and Bangkok. Reports of the occurrence of this disease have been made in Trinidad and in Hawaii but in neither case has it seemed to be either an infectious or hereditary disease of any importance. Types of cane plants corresponding to most of the types of sereh in Java occur in Porto Rico. These types have varied from the normal owing to such unfavourable conditions as drought, excessive moisture, borer and other injury. In no case in Porto Rico does it seem to be a true disease.

As control measures, the following have been recommended in Java :—

1. The selection of disease-free cuttings from disease-free areas, or the planting of cane especially for seed in sereh-free districts.

2. Good seed selection and the use of the younger part of cane for cuttings.

3. The use of the more resistant varieties of cane.

4. Arrangement of cane fields so that a new planting of healthy seed will not lie adjacent to a field of sereh-diseased cane.

5. Increased working of the soil to promote root development.

Further points recommended for control were as follows :—

1. Disinfection in various ways both of the cuttings and of the ground.

2. Early transplanting.

3. An immunizing of the cane against sereh.

As a result of the immense amount of work done on this disease, although the cause has not been positively ascertained, nevertheless practical means of control have been obtained : (1) selection of seed as to quality and variety, and (2) growing seedlings in the mountains in sereh-free districts and transplanting to the lower cane fields.

[MOTTLING DISEASE.]

[Within the last three years there has appeared in Porto Rico a new and most alarming disease. From an initial small area it has spread or appeared spontaneously over a large part of the northern half of the island. The loss to date is believed to have reached half a million dollars, the damage resulting from stunting of the plants, reduction in amount of the juice, and final death of the stools. In addition such juice as is obtained is very difficult to handle in the mill. The disease follows a course of approximately three years, appearing in the first on a few scattered stools in a given field, increasing in the next to possibly a 50-per cent. infection, and in the third, completely overcoming the cane.

The symptoms are first a peculiar mottling of the leaves; nearly white linear spots and lines on a normal green background, or in early stages yellow-green lines and blotches. The mottling is quite distinct from the spotting occurring in cases of deterioration or 'root diseases'. In more advanced cases cankers appear on the stalks, long linear, brown to gray in colour, and sunken. There is a greater tendency for cracks to appear, and the internodes of stalks in the canker stage are generally shrunken. There are no other symptoms such as bud rot, internal discoloration, abnormal clinging of the leaves, etc. No root abnormalities have been noted to date.

No cause has been found for the phenomenon, either parasitic or environmental. It is now believed to be a type of degeneration possibly induced by a combination of unfavourable weather and poor agricultural practices.

The disease has attacked every one of the many varieties tried out to date, although certain ones have been much more subject than others. The Otaheite or common white cane of the country and other white canes have been uniformly seriously attacked. During the past year the striped cane has fallen a prey, and not one type is yet known which resists the disease to a satisfactory extent.

This disease has been treated in detail in the publications of the Porto Rican Insular Experiment Station ([illegible]). J.A.S.]

WITHER-TIP.

A disease reported first from Hawaii. Characterized by the leaves dying back from the tip. The midrib remains green long after the rest of the leaf is dead.

Cobb reported various fungi associated with the disease but in no case proved a connexion. A pycnidial fungus, a fungus resembling Colletotrichum, and a third with long setae and spherical spores were found on the diseased leaves.

In Porto Rico severe cases of wither-tip have occurred twice during the years 1911-14, and on the diseased leaves were found *Hormiactella sacchari* (see Plate V, Fig. 1), *Periconia sacchari*, (see Plate V, Fig. 2), and *Colletotrichum falcatum*. The connexion between these fungi and the disease has not been proven.

CHLOROSIS.

Chlorosis as a serious disease of cane has been reported from Porto Rico, where it occurs on the south or dry side of the island. It is found also in Cuba, Jamaica, Antigua, and Barbados.

The cane affected with chlorosis becomes pale green and may eventually become a sort of milk white. The chlorotic condition retards the growth of young plants and sometimes causes death. The condition may be permanent on certain kinds of land, or may vary with the amount of rainfall, or water applied. Barbados Seedling 1753 has shown the greatest resistance to this condition. Applications of sulphate of iron to the soil or to the leaves succeed in temporarily restoring the green colour to the leaves.

Chlorosis always occurs on very limy soils, but the severity of the condition is not directly proportionate to the amount of lime present.

[In Jamaica chlorosis occurs on some northside coast estates. It is a chronic condition on certain restricted patches, but during wet years it is more or less marked over considerable areas. It is restricted to soils with a high marl content. S. F. A.]

[Chronic chlorosis occurs in small patches here and there in Barbados, and is common in certain localities in Antigua, where the areas subject to it are known as gall patches. H. A. Tempany ([39]) has shown that the condition is due in Antigua to the presence of soluble material, indicated by analysis to be sodium carbonate ('black alkali'). This is believed to originate from interaction between the calcium carbonate of the soil and sodium chloride brought up in solution from saliniferous deposits at deeper levels. The condition can occur in soils containing much less lime than may be found in soils permitting normal growth. W. N.]

THE CONTROL OF CANE FUNGI.

It is impracticable by present methods entirely to eliminate fungi from the cane field It is, rather, the aim of the good agriculturist, while reducing the fungi to a minimum, to produce vigorous canes so that whatever fungi are present will have little serious effect. It is out of place here to discuss ordinary methods of producing vigorous canes, such as selection of good soil, thorough preparation of the soil, good drainage, selection of strong seed, proper planting, and proper cultivation. We shall discuss here what is primarily the control or reduction in amount of the fungi. This work is based upon several principles which are founded upon a knowledge of the cane fungi as given in the preceding pages. The most important of these principles are as follows:—

1. That healthy seed tends to give healthy plants, and conversely, unhealthy seed is likely to give unhealthy plants or no plants at all.
2. That certain canes are more resistant to disease than others, hence cuttings from such canes will produce plants more resistant to some diseases.
3. That means may be taken to disinfect seed or to provide it with a protective covering.
4. That the less food material there is for cane fungi, the less they will develop; therefore other plants that harbour cane fungi should not be grown for a series of years, nor should such plants be grown in rotation with cane.
5. That many cane fungi infect the cane only when injured or in an otherwise unhealthy condition, therefore all means should be taken to avoid such conditions.

6. That certain fungi develop only in mature canes, therefore care should be taken that infected mature cane is not allowed to stand long before cutting.

Attention to these principles, in addition to the practice of ordinary good farming methods will do much to control both the amount of fungi in the field and the effect of the fungi upon the cane.

The application of the preceding principles is here given in some detail under their respective numbers :—

1. By healthy seed is meant seed free from borer injury, free on the outside from the mycelial coating of *Marasmius Sacchari*, *Himantia stellifera*, *Sclerotium Rolfsii*, and any signs whatever of mould ; on the inside free from any red discoloration or black discoloration. The stalk from which the cutting is selected should be affected with neither the rind disease (*Melanconium Sacchari*) nor the red-rot (*Colletotrichum falcatum*), and should not be affected with the root disease (*Marasmius Sacchari*), the red rot of the leaf-sheath (*Sclerotium Rolfsii*), nor by any unfavourable conditions. In brief, a perfectly sound stalk should be used for the seed.

2. That certain varieties of cane are more resistant than others to the pine-apple disease, has already been mentioned under the discussion of the fungus (Thielaviopsis) causing that disease. It has also been indicated in the discussion of *Marasmius Sacchari* that there is a variation in resistance among the varieties in regard to their susceptibility to this fungus. Recognition of this should be made in selecting canes for planting. [Good results have been obtained in British Guiana by substituting D. 145 and D. 118 for Bourbon or D. 625 in badly affected fields. C. K. B.]

3. Ordinary Bordeaux mixture either of the formula 2 2-50 or 4 4-50 will serve both as a disinfectant to destroy all spores of injurious fungi on the seed, and as a protective covering to prevent the entrance of fungi. It will not destroy fungi in the interior of the seed without at the same time injuring the seed. The interpretation of the formula is pounds of lime, pounds of copper sulphate, and gallons of water.

[An improved form of Bordeaux mixture is prepared as ollows :—

Formula.—Blue-stone	..	...	...	14 lb.
Quicklime	...	...	...	9 ,,
Water ...	...	...	..	100 gal.

Method of mixing.—Use the blue-stone stock solution at ful strength. Dilute the lime stock solution fully with water. Pour the blue-stone solution into the diluted lime solution and Bordeaux mixture (of a sky-blue colour) results at once.

Example.—To make 100 gallons of Bordeaux mixture, stir thoroughly the lime stock solution ; then take out 9 gallons

and pour through a coarse strainer (rejecting all lumps) into a galvanised-iron tank or wooden vat. Add 77 gallons of water, thus obtaining 86 gallons of 'milk of lime'. Stir, and then pour into the midst of the lime 14 gallons of the blue-stone stock solution, and Bordeaux mixture is obtained. Stir before use. C.K.B.]

4. It has been noted in preceding pages that at least half a dozen cane fungi occur also on other plants. Perhaps the most important of these is the cause of the pine-apple disease (*Thielariopsis paradoxa*). This disease occurs on cane, on pine-apple, on bananas, and also on the coco-nut palm. If cane land is put into pine-apple, or vice versa, it would be advisable to know the extent of this disease in these fields in the preceding years, otherwise there might result an unexpected poor germination of the cane, or a poor setting of the pine-apple slips.

The other important diseases occurring on other crops than cane are the root diseases caused by *Marasmius Sacchari* and *Himantia stellifera*. These two fungi occur also on grasses. For this reason allowing the land to lie fallow in pasture, while of some benefit, will not serve to kill out these fungi. By far the better way is to plant year by year sections of the land in sword beans or other leguminous crop. In this way the fungi are pretty well starved out; and the land is otherwise improved more than it would be if turned into pasture.

5. Injured cane undoubtedly serves as a means of infection. Therefore any reduction in the amount of borer injury, cattle injury, white grub injury, rat injury, or anything similar will do much to reduce the amount of fungus infection.

6. *Melanconium Sacchari* and *Colletotrichum falcatum* growing in mature cane may quickly destroy the greater part of the sugar content of the stalks, the rapidity of this action depending upon the vigour of the cane, variety of cane, age of cane, and weather conditions. On certain soils, the canes often appear to have little resistance. While they may have attained a good size, they may, nevertheless, after maturity, when infected with these fungi, become worthless in a month's time. Infection in mature canes should therefore be carefully watched and at the first sign the cane should be cut as soon as practicable.

[The methods of treatment of root disease which have been adopted in British Guiana and found to be successful are :—

1. *Improved cultivation methods*.—a. It is generally supposed that the fungus is weakly parasitic, and vigorously growing canes are less liable to attack than those which are weak. Careful methods of cultivation and drainage tend to diminish the attacks from the fungus.

b. Ratoons are more badly attacked than plant canes. Special attention to the treatment of ratoon canes and the abandonment of ratooning in badly affected fields should be practised.

c. The throwing of badly infected fields out of cultivation and flooding of the land for a couple of years is a method which has given good results, the object being to diminish the amount of the fungus by robbing it of its food supply.

2. *Isolation.*—The appearance of the fungus in isolated stools or clumps of stools along with its spread by the growth of the mycelium underground naturally offers a means of checking its spread by isolation by trenches. These should be made 24 inches deep and 12 inches wide, and should enclose the infected area.

3. *Sanitation.*—a. The destruction of diseased stools is essential for the control of the disease. Affected stumps should be dug up and burnt. Trash from infected areas should be burnt. Lime applied, as nearly unslaked as possible and at the rate of 1½ tons per acre, to these infected areas before supplying is beneficial as a fungicide.

b. The selection of plants for cuttings from infected fields should, where possible, be avoided.

c. The propagation of the plant by the practice known as 'stumping' tends to spread the disease unless special care is taken to avoid the use of stumps from infected fields.

4. *Disease resisting varieties.*—There are some canes which show a marked resistance to the disease, although it is doubtful as to whether any cane is immune. The varieties which are generally badly affected in British Guiana are Bourbon, D. 625, B. 208, and Green Transparent. The two former suffer more than any other varieties. Of the others, D. 109 is frequently affected. D. 145 and D. 118 are more resistant. D. 216 and D. 159 are not reported to be affected.' The planting of the more resistant varieties in badly affected fields for a period of several years for the purpose of checking the spread of the disease should, where feasible, be adopted. Supplying infected stools with plants of more resistant varieties should also receive attention. The object of these methods is to reduce the quantity of the fungus in the soil to a minimum before replanting with the more susceptible varieties. C. K. B.]

[Wide experience shows that the most reliable method of avoiding root disease in dry districts lies in the alternation of crops, while considerable benefit is derived from any system which permits the fields to be cleared of sugar-cane for even a short period. The general avoidance of even first ratoons on the lower and drier levels in Barbados is without much doubt principally due to the necessity of clearing and thoroughly working the land each year in order to escape the effects of root disease. Even this system does not usually permit of the growing of more than two crops of cane in succession, and where root borer is also prevalent, strict alternation is desirable.

The persistence of root disease in localized patches usually indicates a need for special attention to soil conditions.

Cases of early infection in plant canes would appear to be due to the planting of infested cuttings, especially of susceptible varieties. The advice to avoid cuttings from diseased fields appears unpractical to many planters, because they have found, in favourable years, that such cuttings have given as good results as any others. The same consideration applies to advice to refrain from ratooning infested fields.

In St. Kitts, where the use of B. 208 persists in certain districts, that variety is regarded as especially susceptible to root disease. W. N.]

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EXPLANATION OF PLATES.

Plate I.

Fig. 1. *Gnomonia iliau.* asci.
3. „ „ vertical section of perithecium.
2. *Melanconium iliau,* conidia.
4. „ „ stromata.

Plate II.

Fig. 1. *Melanconium Sacchari,* vertical section of stroma.
2. „ *iliau* „ „ „ „

Plate III.

Fig 1. *Ustilago Sacchari,* showing whip-like diseased part, and spores.
2. *Leptosphaeria Sacchari,* asci and spore.
3. *Sphaerella Sacchari,* surface view of perithecium.
4. *Cytospora Sacchari,* showing surface view of pycnidia, vertical and longitudinal sections of pycnidia, spore, and sporophore.
5. *Eriosphaeria Sacchari,* asci and spore.

Plate IV. *Marasmius Sacchari*

Plate V.

Fig. 1. *Hormiactella Sacchari*, sporophores, and sori.
2 *Periconia Sacchari*, sporophores, and spore.
3. *Odontia Sacchari*, cystidium, and basidium with single spore.
4. *Himantia stellifera*, hypha with stellate crystal, and swollen bodies.

Plate VI.

Fig 1. *Thielaviopsis paradoxa*, sporophores of micro- and macroconidia.
2. *Cercospora vaginae*, sporophore and spores.
3. „ longipes „ „ „
4. *Cephalosporium Sacchari*, sporophores and spores.

Plate VII.

Fig. 1. *Colletotrichum falcatum*, sporophores and spores.
2. *Cercospora Kopkei*, sporophores and spores.
3. *Helminthosporium Sacchari*, sporophores and spores.
4. *Sphaerella Sacchari*, asci.

Note: The illustrations have for the most part been made as follows: photographic copies were made from various publications and redrawn, and then extraneous parts bleached out.

Due credit should be given to the original sources of these drawings, as follows:—

Plates I, II, III, Figs. 3 and 5, Plate VII, Figs. 1 and 4, to the *Bull. of the Hawaiian Sugar Planters' Experiment Station.*

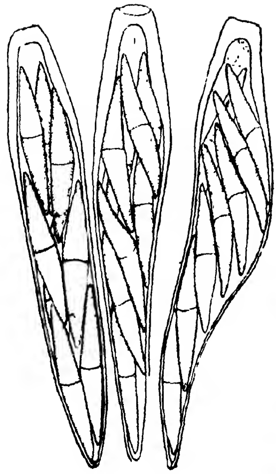
Plate III, Figs. 1 and 5, Plate VI, Fig. 2, Plate VII, Fig. 3, to Wakker and Went.

Plate III, Fig. 2. Plate VI, Figs. 2, 3, and 4, Plate VII, Fig. 3, to *Mem. of Dept. of Agric. in India.*

Plate IV, to Cuban Experiment Station.

Plate III, Fig. 4, Plate V, Plate VI, to Porto Rican Insular Experiment Station.

PLATE 1.



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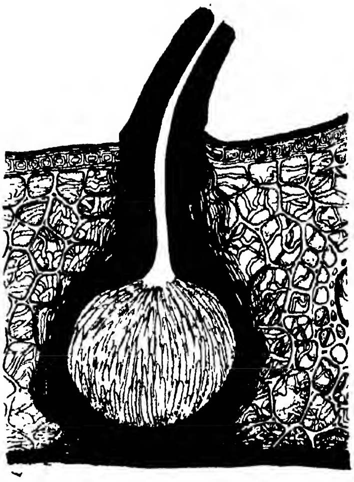

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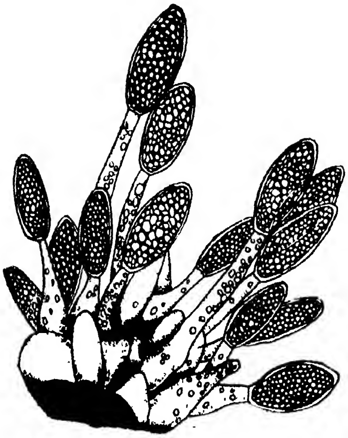

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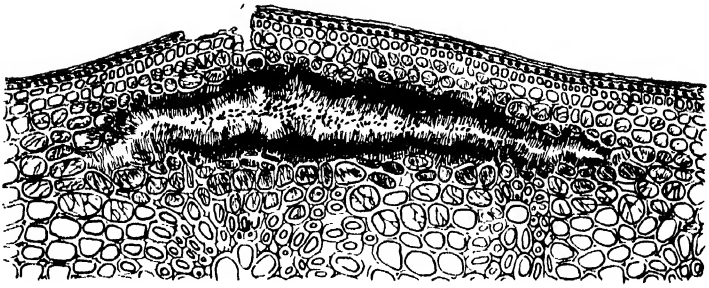

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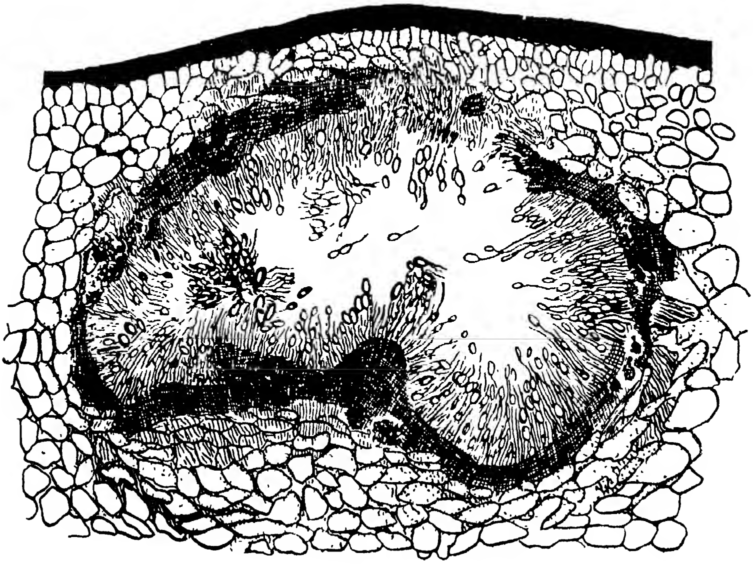

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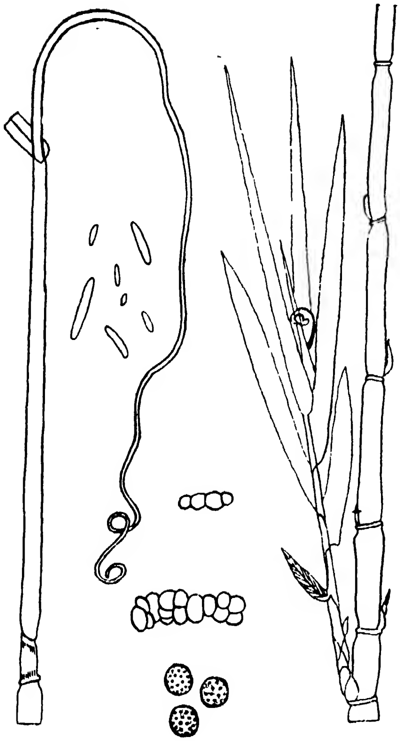

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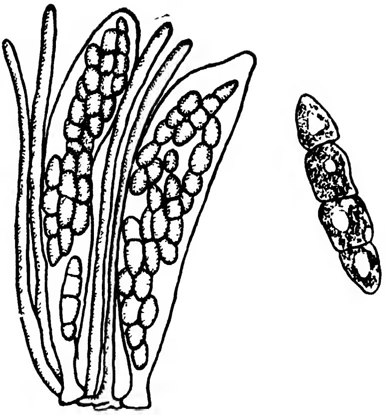

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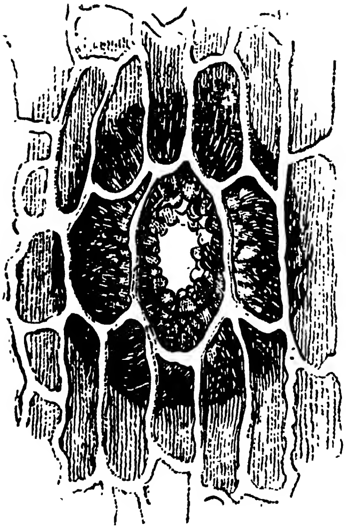

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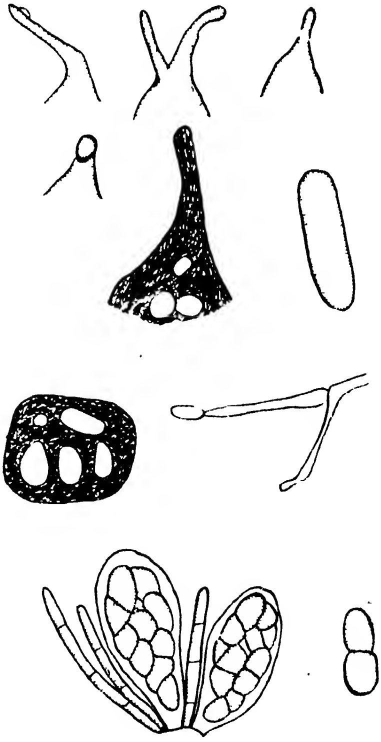

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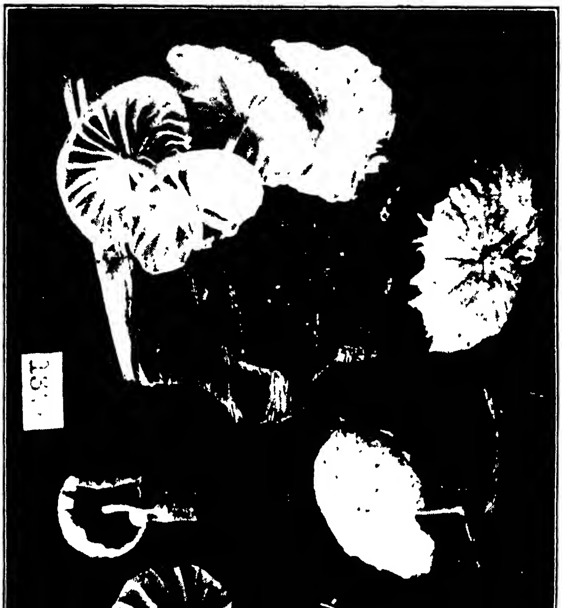

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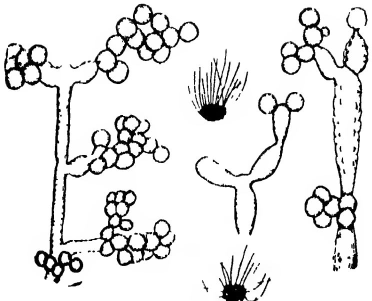

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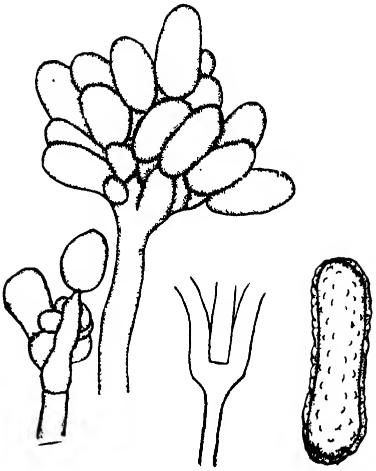

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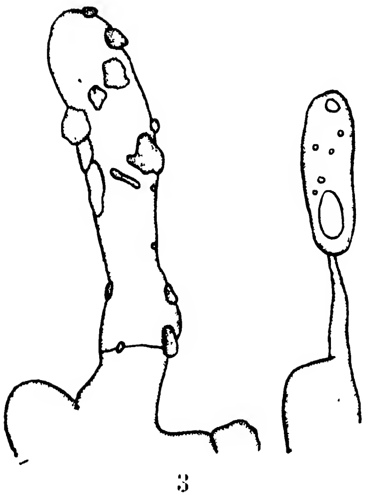

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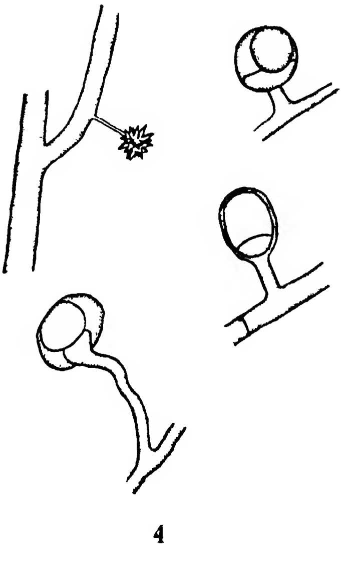

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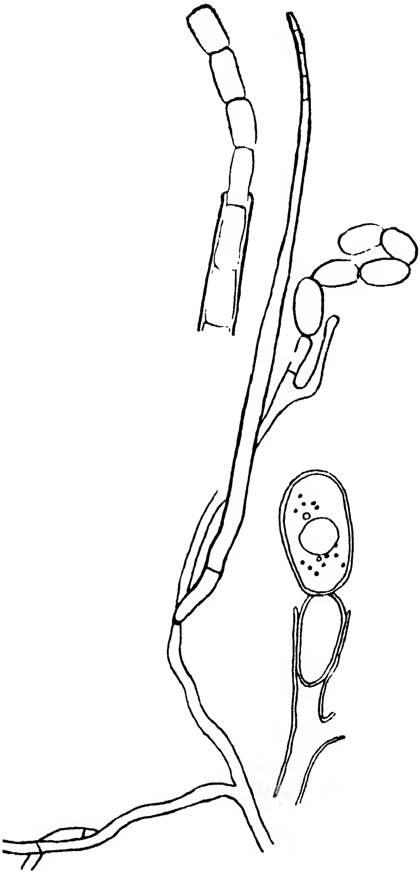

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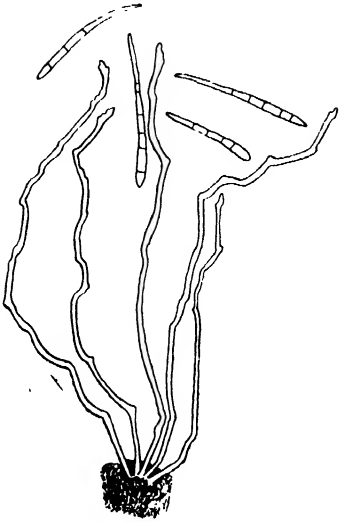

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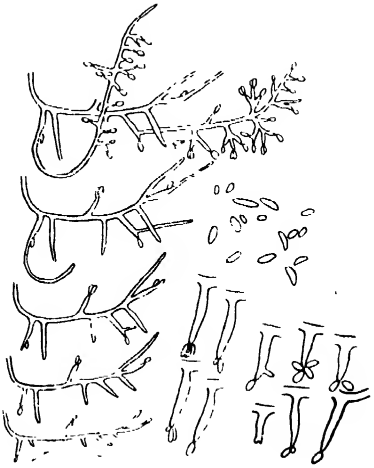

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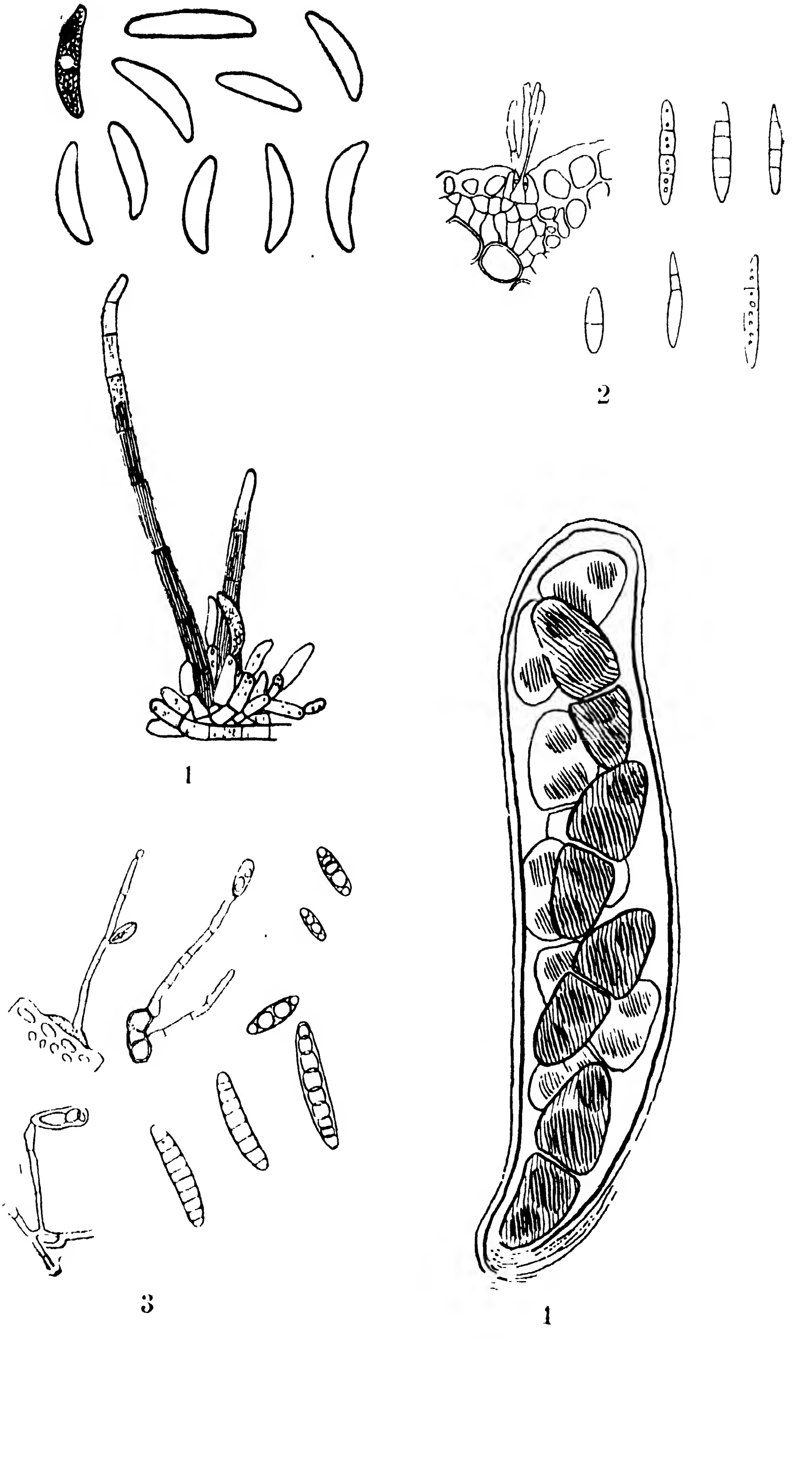

REPORT ON THE PREVALENCE OF SOME PESTS AND DISEASES IN THE WEST INDIES DURING 1916.

(Compiled from the Reports of the principal local Agricultural Officers.)

This is the eighth report of this series, the latest previous one, that for 1915, appearing in the *West Indian Bulletin*, Vol. XVI, p. 1. The present report covers the period January to December 1916, and has been prepared in the same way as previous ones, from information supplied by the Agricultural Officers in the several islands.

ENTOMOLOGIST'S VISITS. During the year the Entomologist visited St. Vincent in January, and spent a day in Antigua in March on the way to the Cotton Conference in St. Kitts.

The principal object of the visit to St. Vincent was to investigate the condition of cacao cultivation more particularly in connexion with the occurrence of thrips as a serious pest on cacao. The condition of the citrus and cotton industries was also investigated, and the minor crops received consideration. Abstracts of the report on this visit have been published in the *Agricultural News*, Vol. XV, pp. 206 and 222, under the heading Cacao Thrips and Die-back in St. Vincent, and in the Annual Report of the Agricultural Department, St. Vincent, for the year ended March 31, 1916. A short summary of this report also appeared in the *Review of Applied Entomology*, Vol. IV (1916), p. 416.

MYCOLOGIST'S VISITS. In company with the Entomologist the Mycologist visited St. Vincent in early January with the principal object of investigating the reasons for the poor condition of certain cacao cultivations on the windward coast. Apart from a few patches of Rosellinia root disease, the general type of failure found took the form of a progressive die-back, in which the trees are subject to repeated severe attacks of thrips, and the dead and dying branches are infested with the die-back fungus *Lasiodiplodia Theobromae*. The conclusion was reached that as result of the remarkable lightness and permeability of the St. Vincent soil, cacao in that island, in spite of the rather heavy rainfall, is being grown very near to the margin of the conditions of moisture and humidity necessary for its successful cultivation. Under these circumstances there is a special need for the provision of fairly dense top shade, wind belts and marginal screens, for the use of quick-growing plants to fill in open spaces, and for the supply of coarse organic manures and mulches to make the soil more retentive. The matter was discussed at length in a joint report which has been separately published.

Attention was also given to the internal boll disease of cotton and the 'burning disease' of arrowroot, both of which have since been the subject of papers in the *West Indian Bulletin*.

In March the Mycologist took part in the Cotton Conference held at St. Kitts.

In May and June an extensive tour was made in Dominica for the continuation of the study of root diseases of lime trees. The results as regards the most important of these have since been published.

CLIMATE.

GRENADA. The dry season (February to May) was very mild and unusually moist. Heavy rains in November were general over the island. The remainder of the year was practically normal. The weather was very favourable, on the whole, for all crops.

ST. VINCENT. The rainfall for the year at the Botanic Station was 137·63 inches, being unusually heavy in October and November. The abnormal rainfall in these two months caused great damage to cotton.

ST. LUCIA. The rainfall for 1916 at the Castries Station was 110·48 inches, this being 18·29 inches in excess of the average rainfall for the last twenty-six years. The rainfall was particularly heavy in the months of June, August, September, and October. The driest month was April. Heavy winds were experienced in August, September, and October. The cacao crop suffered from excessive rains which favoured fungous diseases. A reduction in the acidity of the lime fruits was noticed, but the trees benefited in most cases by the rains, which checked the snow and mussel scales, probably producing conditions favourable for the development of their fungous enemies. Sugar cultivation benefited in the dry districts, but suffered somewhat in the valleys with clay soils.

DOMINICA. The rainfall for the year was 84·42 inches, which is only a few inches more than the mean rainfall for over twenty-four years. The rainfall may therefore be considered sufficient without being excessive, and the distribution was, on the whole, satisfactory. The outstanding feature of the weather conditions was the hurricane experienced on August 28, which in certain districts did a very considerable amount of damage, and, as it happened, those districts which have of late years suffered most severely from fungous diseases also suffered most in the recent hurricane. Up to August 28 the weather conditions must have been very satisfactory for the development of the lime crop, for the island would have produced a record crop.

MONTSERRAT. There was a comparative absence of high winds during the period of growth of the cotton crop, excepting that on August 28 a severe gale did considerable damage, particularly to the windward crop. April, June, and December were the dry months, while excessive rains fell in October. For the cotton crop at windward the dry month of June was very harmful, while at the leeward side, where the crop was a month behind that at windward, the only prejudicial weather experienced was the excessive rainfall of October.

For the lime crop the dry month of June resulted in the

would seem that the dry month of December was connected with the partial failure of the onion crop.

ANTIGUA. The mean rainfall for the island was considerably above the average for the last three years. The first nine months of the year from an agricultural point of view were all that could be desired. The heavy rains which fell in October and November did harm to some crops. Ratoon canes suffered considerably, especially in badly drained land. Although the cane crop for 1916-17 will not be as good as the one for the preceding year, it will however be much above the average. Limes and coco nuts have made good growth. The heavy rains mentioned above damaged newly transplanted onion seedlings, and some cotton ready for reaping was also lost on this account.

ST. KITTS. The rainfall for the year was nearly 66 inches. The first three months of the year were suitable to plant growth. April was a dry month, and from May to the end of October the weather was wet. Generally speaking, the weather has been very suitable to the sugar-cane crop. With the exception of December the canes received no check in growth. The dry weather in December was unfortunate, as it affected the germination of the cane plants, and also ripened up the plant canes and ratoons. The cotton crop, especially in the northern district, was severely affected by the wet weather, and except where planted early, the crop was generally a failure. In the Valley district the dry weather of December resulted in the cotton plants producing a much larger number of bolls than was expected.

NEVIS. The rainfall for the year was 64·04 inches. The distribution, on the whole, was fair up to September, but from October to December the rainfall was exceptionally heavy, over 22 inches falling during the three months. The heavy rains during the latter part of the year did very great damage to the cotton crop throughout the island by producing conditions favourable for the development of fungous diseases.

VIRGIN ISLANDS. The rainfall during the period from May to September was good, well distributed, and beneficial to crops. October and November were marked by heavy rains. The hurricane season was one of exceptional activity, there being a total of eight cyclonic disturbances during this season. Most of these passed by the islands, but the cyclone of October 9 will long be remembered. Up to that date the crops promised exceptionally well, but this severe storm practically destroyed all crops. The rainfall for the year was 69·65 inches.

PART I.—INSEST PESTS.

BY J. C. HUTSON, B.A., Ph.D.,

Entomologist on the Staff of the Imperial Department of Agriculture for the West Indies.

SUGAR-CANE.

MOTH BORER (*Diatraea saccharalis*, Fabr.).

ST. VINCENT. Generally present, locally severe.

ST. LUCIA. Prevalent in most cane fields, but no serious outbreaks.

MONTSERRAT. Plentiful in Grove Station at the beginning of 1916. No observations elsewhere.

ANTIGUA. Generally present.

ST. KITTS. Moth borer has not done very much damage during the past season owing to the favourable weather conditions, but could be found on all estates.

NEVIS. Occurred to a fairly great extent throughout the island.

VIRGIN ISLANDS. No observations.

WEEVIL BORER (*Metamasius sericeus*, Oliv.).

ST. LUCIA. Not observed.

MONTSERRAT. No observations.

ANTIGUA. General in cane fields.

NEVIS. Not observed during the year.

ROOT BORERS (*Diaprepes abbreviatus*, L., and others).

ST. VINCENT. Generally distributed.

ST. LUCIA. Present but no serious damage reported.

ANTIGUA. *Exophthalmus esuriens* found in some fields in southern part of the island.

ST. KITTS. *D. abbreviatus* occurs on estates in different parts of the island, and on one or two it is usually accompanied by root disease (Marasmius). It is however not so prevalent as in past years. *E. esuriens* has greatly decreased in numbers, and the damage caused by this insect during the past year is very much less.

NEVIS. *D. abbreviatus* was not observed during the year. *E. esuriens*. The adult insect was seen in different parts of the island in cotton fields and on hedges.

VIRGIN ISLANDS. Very abundant in the adult stage in May and June.

HARD BACK GRUBS.

ST. LUCIA. No damage reported.

ANTIGUA. *Lachnosterna* sp. common in heavy lands in centre of island.

NEVIS. Grubs of *Ligyrus tumulosus* occur in nearly every cultivated field.

WHITE ANTS (TERMITES).

ANTIGUA. Found commonly in some districts, but do no apparent damage.

ST. KITTS. These insects are doing no damage on the Pond estate where they were originally found, and at Buckleys estate there has also been less damage.

MISCELLANEOUS INSECTS.

GRENADA. An outbreak of froghopper occurred in November, and was investigated by C. B. Williams, Entomologist-in-Charge of Froghopper Investigations in Trinidad. Froghoppers were found to be fairly well distributed throughout the island, but actual damage occurred on two estates only.

ANTIGUA. Mealy-bug, common.

ST. KITTS. Grasshoppers were very prevalent, and did much damage to the young canes, especially in the Valley district. They occur usually about February and March. Poisoned bait of Paris green and bran was applied successfully in a few instances.

NEVIS. Slight attacks of grasshopper.

COTTON.

COTTON WORM (*Alabama argillacea*, Hubn.).

ST. VINCENT. Generally present, locally severe.

ST. LUCIA. No estate cotton grown during the year, and no pests observed.

MONTSERRAT Appeared in certain districts in July, and throughout the season was effectively controlled. Not nearly so severe as in previous season. There was a marked cessation of attacks on the development of the second growth of the plants in the months of October and November, and very little dusting was required at that time.

ANTIGUA. Attacked old plants in January, and appeared again in June, and from then on several severe attacks were experienced during the year.

ST. KITTS. The cotton worm did very little damage during the past season, although generally present.

NEVIS. Fairly prevalent during the early part of the season but kept in check by poison. Practically absent later in the season after the heavy rains.

VIRGIN ISLANDS. The cotton worm usually appears in these islands late in the year, October, November and December In 1916 the cotton plants in practically all districts were defoliated by the gale, and no cotton worms were observed or reported.

BOLL AND CORN EAR WORMS (*Heliothis* and *Laphygma*).

MONTSERRAT. Neither is regarded as a pest in the island.

ANTIGUA. Fairly common. Little damage.

NEVIS. Not known to occur during the year.

COTTON STAINERS (*Dysdercus* spp.).

ST. VINCENT. *D. delauneyi*, Leth., was generally present, and severe attacks were experienced.

MONTSERRAT. Did generally less damage than for many years, but became prevalent in all districts at the close of the year, by which time most of the cotton had been picked. The amount of stained cotton in the crop will be small. Advantage of collecting stainers in early part of the season has been further demonstrated. Certain districts became infested earlier in the season than others.

ANTIGUA. Severe attacks experienced towards end of season in one district. This insect probably does more damage than is realized locally.

ST. KITTS. Cotton stainers were found where cotton was kept out of season, but little damage is experienced in St. Kitts from this pest, owing to the fact that the cotton matures early, and the plants are buried under early for the planting of the canes.

NEVIS. Very prevalent during the season from September onwards.

VIRGIN ISLANDS. Observed attacking *Thespesia populnea*, but no damage reported to cotton. The numbers appeared to be less than in previous years.

BLACK SCALE (*Saissetia nigra*, Nietn.).

WHITE SCALE (*Hemichionaspis minor*, Mask.).

GRENADA. A white scale on the stems of cotton is generally distributed in Carriacou.

ST. VINCENT. Black scale. Generally present.

MONTSERRAT. More black scale than usual present on plants at the close of the season. White scale is scarcely ever seen on cotton plants, and neither insect is regarded as a pest.

ANTIGUA. Both scales observed, but not particularly numerous.

NEVIS. Black scale. Observed in a few places, but not to any great extent.

White scale. Observed on old cotton, but not doing any damage.

FLOWER-BUD MAGGOT (*Contarinia gossypii*, Felt.).

VIRGIN ISLANDS. Observed only in the Virgin Islands where it is reported from the Experiment Station. Present in considerable numbers. Probably responsible for a good deal of boll-dropping in the less sunny localities.

LEAF-BLISTER MITE (*Eriophyes gossypii*, Banks).

GRENADA. Generally distributed in Carriacou.

ST. VINCENT. Generally present.

MONTSERRAT. Did no serious damage anywhere. Its occurrence is now as a rule quite sporadic, and it is not regarded as a serious pest.

ANTIGUA. General, particularly on old cotton.

ST. KITTS. This pest always appears on the cotton plants when they are maturing, but is not feared, as the plants are turned in before any damage is done. The only risk is where young cotton is planted near older plants infested with the mite, but this rarely occurs in St. Kitts.

NEVIS. Very prevalent this season, especially towards the end, due, it is considered, to the fact that the old cotton was left standing, and the preparation for the new planting was hurried.

VIRGIN ISLANDS. Abundant in nearly all cultivations.

MISCELLANEOUS INSECTS.

ST. VINCENT. An unknown species of thrips and a Cryptorhynchus borer occurred in some districts.

NEVIS. Lachnopus attacked young cotton at one estate in July and August doing a considerable amount of damage.

VIRGIN ISLANDS. Aphis was present in some localities.

CACAO.

THRIPS (*Heliothrips rubrocinctus*, Giard.).

GRENADA. Generally distributed, and severe in some localities.

ST. VINCENT. Generally present, locally severe.

ST. LUCIA. A few slight cases noticed, but no serious injury reported except in the Roseau valley.

DOMINICA. No serious outbreak of thrips was brought to the notice of the Department during the year, and none was observed whilst travelling. It is not difficult to find specimens of this insect in most localities where cacao is grown.

In Grenada thrips was reported in September to be severe in places, but general distribution normal. In October it was still severe locally, while in November, although prevalent on some estates, it had decreased after heavy rains. In December it was stated to be going off, and the trees were recovering.

BEETLE (*Steirastoma depressum*, L.).

GRENADA. Locally severe.

SCALE INSECTS AND MEALY-BUGS.

GRENADA. Recorded during the year.

MISCELLANEOUS INSECTS.

GRENADA. Acrobat ant (*Cremastogaster* sp.) generally distributed.

White ant. Of doubtful occurrence.

DOMINICA. The serious outbreak of root grubs which occurred in one of the cacao plots at the Botanic Gardens in 1914, and which at the time was treated with carbon bisulphide, has not reappeared. The plot is slowly recovering from the bad effects of the attack.

LIMES AND OTHER CITRUS.

SCALE INSECTS.

GRENADA. The purple, green, snow, and West Indian red scales were generally distributed. The green scale occurred on young trees, and the snow scale was severe in drier localities of Grenada, and particularly bad in Carriacou.

ST. LUCIA. Generally present throughout the island, but, on the whole, there have been few severe attacks. Under normal conditions the parasitic fungi keep the scales under control, but where the trees are neglected, or planted in unfavourable conditions, attacks by scale insects are severe.

DOMINICA. The island as a whole—and especially old-established cultivations—continues free from attacks of scale insects. Young trees, three to five years old, are not as fortunate, and are often infested with scales to such an extent that the tops are seriously injured. Generally they shoot out again from the stumps, and in time gradually re-establish themselves.

MONTSERRAT. Serious attacks of Lantana bug at leeward district from April to June, followed later by much black blight. Near the close of the year there was a perceptible development of purple scale, and the usual dying of branches on certain areas in the same district.

ANTIGUA. General on lime trees, but perhaps less common than in previous years.

NEVIS. The purple and green scales were observed on limes throughout the island, and in the dry districts have been mainly responsible for the death of a fair number of lime plants.

VIRGIN ISLANDS. No observations made.

BARK BORER (*Leptostylus praemorsus*, Fabr.).

ST. LUCIA. Several severe cases have been recorded during the year, and in each case the owner's attention has been called to it. On one very large estate every tree examined showed the effects of this pest, and it must be regarded as the most serious pest to the lime cultivation in the island at present. Bad pruning and general neglect have exposed the trees to attack in every case examined.

DOMINICA. Not a serious pest during the year.

MONTSERRAT. Always more or less present on lime trees.

TWIG BORER (*Elaphidion mite*).

This insect has not been observed in any of the islands during the year.

ROOT BORER GRUBS (*Diaprepes* and *Exophthalmus*).

GRENADA. Diaprepes damaging twigs where canes are planted between limes.

ST. LUCIA. No Diaprepes found or recorded although a search was made for these on several occasions.

DOMINICA. These do more damage to young trees in the island than is commonly realized by planters. Not particularly serious during the year.

MONTSERRAT. The adults of Exophthalmus are most conspicuous on young trees, but have not been more prevalent than usual. In established fields the insects themselves, or the damage they do, are rarely noticeable, though the damage to roots seems universal.

Collections of these weevils were made every month from April to December 1916, a total of about 7,800 being taken in that period on an acre experiment plot at Belle.

ANTIGUA. Locally severe.

About 70,000 adults of Exophthalmus were caught and destroyed on one estate during the early part of the year.

NEVIS. Not observed.

VIRGIN ISLANDS. Adults of Diaprepes were serious pests to young lime plants in some localities, the beetles eating the edges of the young leaves.

MISCELLANEOUS INSECTS.

ST. LUCIA. Mole crickets caused severe losses to lime seedlings in some localities.

MONTSERRAT. Larvae of bagworm damaged navel orange at Grove Station.

SWEET POTATOES.

SCARABEE (*Euscepes batatae*, Waterhouse).

ST. VINCENT. Generally distributed.

ST. LUCIA. Neither reported nor observed.

MONTSERRAT. Not particularly prevalent during the year, but no definite observations.

ANTIGUA. Common in peasant holdings. Sweet potatoes grown on estates are generally free from this pest.

ST. KITTS. No record during the year.

NEVIS. Occurred in different parts of the island, but not to any great extent.

CATERPILLARS (*Protoparce cingulata*, and others).

ST. LUCIA. A few cases observed.

MONTSERRAT. The only caterpillar noticed as damaging the leaves of sweet potatoes is that of the moth, *Sylepta helcitalis*.

ANTIGUA. Several mild attacks experienced.

NEVIS. None observed.

VIRGIN ISLANDS. No observations made.

THRIPS.

GRENADA. Of doubtful occurrence.

Thrips was not observed in any of the other islands.

RED SPIDER (*Tetranychus telarius*, L.).

GRENADA. Generally distributed.

ST. VINCENT. Generally present.

ST. LUCIA. A few cases noticed.

Not noticed in the other islands.

MISCELLANEOUS INSECTS.

GRENADA. Slugs (*Veronicella occidentalis*) were prevalent in some districts of Grenada and Carriacou. The attacks observed seem to occur suddenly, and are generally of short duration.

INDIAN CORN.

CATERPILLARS (*Heliothis armiger*, *Laphygma frugiperda*, and others).

GRENADA. Generally distributed, *H. armiger*.

ST. VINCENT. Generally present, locally severe, *H. armiger* and *L. frugiperda*.

ST. LUCIA. Generally present, *H. armiger*.

MONTSERRAT. Considerable damage is done to each crop by caterpillars that tunnel into the stems of the young corn, but no definite observations have been made to determine what species this is. *L. frugiperda* is generally present on the young corn, but seldom does serious damage.

ANTIGUA. Invariably present and very troublesome. *H. armiger*.

ST. KITTS. *H. armiger* has been very prevalent and severe in some localities. Remedies have been applied such as dusting with earth, and putting a small quantity of Paris green and corn meal in the heart of the plants.

NEVIS. *H. armiger* observed in every field of corn throughout the island.

HARD BACK GRUBS (*Lachnosterna* spp.).

ST. LUCIA. Plentiful, but no damage observed or recorded.

ANTIGUA. Grubs of *Lachnosterna* sp. common in fields situate in central part of island. Responsible for a considerable amount of damage.

MISCELLANEOUS INSECTS.

GRENADA. *Diatraea saccharalis* occurred locally in Grenada and Carriacou.

ST. VINCENT. Mole crickets were generally present and locally severe in the island.

HARD BACK GRUBS. (*Lachnosterna* spp.).

ST. LUCIA. Plentiful but no damage observed or recorded.

ANTIGUA. Grubs of *Lachnosterna* sp. common in fields situated in central part of island. Responsible for a considerable amount of damage.

MISCELLANEOUS INSECTS.

GRENADA. *Diatraea saccharalis* occurred locally in Grenada and Carriacou.

ST. VINCENT. Mole crickets were generally present and locally severe.

MONTSERRAT. Corn leaf hopper (*Peregrinus maidis*) was severe in one locality late in the year. This insect has not been recorded from Montserrat before.

COCO-NUTS.

WEEVIL (*Rhynchophorus palmarum*, L.).

GRENADA. Reported from one plantation of young trees. Gru-gru palms adjacent.

WHITE FLY (*Aleurodicus cocois*, Curtis).

GRENADA. Generally distributed in Grenada, locally severe in Carriacou.

ST. VINCENT. Generally present.

ST. LUCIA. Common throughout all groves in the island when the palms are young, but usually disappears when the head of the palm gets up into the wind.

DOMINICA. Generally distributed, but no serious outbreak was reported or observed during the year.

SCALE INSECTS (*Aspidiotus destructor*, Sign., and others).

GRENADA. Generally present, locally severe. At Morne Rouge cutting off the worst infested leaves and then spraying the trees has given good results.

ST. VINCENT. Generally distributed, locally severe.

ST. LUCIA. Common throughout the island, but no serious injury recorded.

DOMINICA. Generally present, but no serious attack reported or observed.

ANTIGUA. Fairly common, but does little or no damage.

NEVIS. Observed on some plantations, but chiefly on old fronds and not doing much damage.

VIRGIN ISLANDS. Frequently occurs on young palms, severe in some localities.

GROUND NUTS.

PLANT BUGS.

ST. VINCENT. *Edessa meditabunda*, Fabr., generally present, locally severe.

MEALY-BUGS.

ST. LUCIA. Found in experiment plots.

LEAF-EATING CATERPILLARS.

MONTSERRAT. Slight attacks of the woolly pyrol moth (*Anticarsia gemmatilis*, Hubner) were noticed on estate fields.

ONIONS.

CATERPILLARS.

MONTSERRAT. Each year larvae of *Prodenia* sp. have to be persistently collected on seed beds. If this is not done they are capable of destroying the whole of the seedlings.

ANTIGUA. Generally distributed.

NEVIS. Occurred to a fair extent in nursery beds, and in some places did a fair amount of damage.

VIRGIN ISLANDS. Cut worms (*Prodenia* sp.) attacked onions Larvae of *Dilophonota ello* were also taken from onion beds.

THRIPS (*Thrips tabaci*, Lind.).

MONTSERRAT. Not as prevalent as usual.

ANTIGUA. Several attacks experienced during February and March.

NEVIS. Occurred in plot at Experiment Station and other places, but not doing much damage as the crop was almost matured at the time of the attack.

VIRGIN ISLANDS. Troublesome as the dry season approached.

MISCELLANEOUS INSECTS.

ANTIGUA. Grubs of *Lachnosterna* sp. attacked onions in nursery beds in September, and in fields in November.

NEVIS. Grubs were observed attacking young bulbs, but not in large numbers.

YAMS.

SCALE INSECT (*Aspidiotus hartii*, Ckll.).

ANTIGUA. Common, but does little or no damage.

ST. KITTS. This insect can usually be seen on all stored yams, but seems to do little damage.

Green Dressings

LEAF-EATING CATERPILLARS.

GRENADA. Horse beans attacked by *Anticarsia gemmatilis* in some localities.

ST. VINCENT. The larvae of a small moth (*Balloria cistipennis*) were prevalent on beans and peas, causing damage in some cases.

ST. LUCIA. Slight attacks recorded.

MONTSERRAT. Sections of fields of Bengal beans were destroyed by the larvae of the woolly pyrol moth late in the year. Attacks had been noticed much earlier, but severe damage was not done until the time mentioned. Caterpillars are not destructive to any other form of green dressing.

ANTIGUA. No severe attacks experienced during the year.

ST KITTS. Generally distributed.

NEVIS. Not observed.

MISCELLANEOUS INSECTS AND PESTS NOT OTHERWISE PROVIDED FOR.

ST. LUCIA. Stem maggot in mahogany shoots and white cedar trees. Slugs or 'Leather Jackets' (*Veronicella occidentalis*) were very troublesome in vegetable gardens throughout the island.

DOMINICA. The plantain weevil (*Cosmopolites sordidus*), and the slugs (*V. occidentalis*) are two pests commonly distributed. which do a very considerable amount of damage, especially to peasants' gardens.

VIRGIN ISLANDS. The longicorn beetle (*Batocera rubus*) appears to be spreading rapidly, and is attacking trees and plants with milky juices. It also attacks the hog plum (*Spondias lutea*).

Natural Enemies of Injurious Insects.

PARASITIC AND PREDACEOUS.

GRENADA. Parasitized eggs of *Diatraea saccharalis* observed on corn plants.

ST. LUCIA. *Polistes crinitus*, and *P. annularis* worked well in keeping in check the caterpillars on green dressing crops. Domestic ducks kept down 'leather jackets'. (*V. occidentalis*) in gardens.

The following birds have been observed daily feeding at Réunion on mole crickets: *Crotophaga ani. Quiscalus inflexirostris, Tyrannus rostratus, Falco caribbearum.* and the Caille. The latter hunts and digs for the mole cricket.

ANTIGUA. Red-headed, white, and shield-scale fungi fairly common during or soon after a wet period.

ST. KITTS. The local Jack Spaniard (*Polistes crinitus*) has been very prevalent, and is of great assistance in keeping the cotton worm in check.

NEVIS. The parasite (*Chalcis* sp.) of the cotton worm was observed in many fields towards the end of the season.

VIRGIN ISLANDS. *Cephalosporium lecanii* is known to be present as a parasite on scale insects at the Experiment Station.

DISEASES OF ECONOMIC PLANTS.

BY WM. NOWELL, D.I.C.,

Mycologist on the staff of the Imperial Department of Agriculture for the West Indies.

SUGAR-CANE.

ROOT DISEASE (*Marasmius Sacchari*, Wakker, and allied species).

ST. LUCIA. Local attacks ; not severe.

ANTIGUA. Found throughout the island. Severe attacks in a few fields.

ST. KITTS. This disease has not been very apparent owing to the good season ; on one or two estates in a few fields there has been some damage done.

NEVIS. Occurred in nearly every field in the island ; the effect was more marked during the dry period.

VIRGIN ISLANDS. This disease is probably present in many of the neglected cane plots.

RIND FUNGUS (*Melanconium Sacchari*, Massee).

ST. LUCIA. A few slight cases observed.

ANTIGUA. Fairly common.

GENERAL REMARKS.

ST. KITTS. The fields were particularly free from fungoid diseases, the canes being as a rule vigorous and healthy and giving good returns.

COTTON.

WEST INDIAN LEAF MILDEW.

ST. VINCENT. Generally present but not severe.

MONTSERRAT. Not more prevalent than usual.

ANTIGUA. Abundant towards the end of the season.

ST. KITTS. Owing to the heavy rains there was an increase in this disease.

NEVIS. Fairly widely prevalent during the wetter part of the season.

BACTERIAL BOLL DISEASE.

ST. VINCENT. Causes heavy losses during rainy weather.

MONTSERRAT. Very little in evidence during the year.

ST. KITTS. There was a great deal of this disease during the season, particularly in the northern district.

NEVIS. Not observed to occur to any great extent.

ANGULAR LEAF-SPOT.

Usually prevalent by the time the plants are mature.

BLACK ARM.

Accompanies the two previous diseases but is not much noticed.

INTERNAL BOLL DISEASE.

ST. VINCENT. The cause of very heavy losses when the plants became infested with cotton stainers.

MONTSERRAT. Prevalent as usual when cotton stainers infested the plants.

ANTIGUA. Possibly may be more common than is realized at present.

ST. KITTS. The disease has been found in some places but has not caused much loss; cotton stainers have not been plentiful.

NEVIS. Rather abundant during the latter part of the season

OTHER DISEASES OF COTTON.

MONTSERRAT. The greatest loss of cotton occurred during the month of October as the result of an epidemic of the soft rot of bolls caused by *Phytophthora* sp. It is only in damp weather that this trouble develops.

ST. KITTS. Owing to the very heavy rains the season was unfavourable to cotton, and as a general rule the yield was very low. The plants were very large and shedding occurred more than usual. The dry weather of December caused much improvement in some places.

CACAO.

ROOT DISEASE (*Rosellinia Pepo*, Pat.).

GRENADA. Caused serious losses in some localities.

ST. LUCIA. Generally distributed but under control.

DOMINICA. No serious effort is made to cope with this disease on several estates where its presence is known to the owners. Under the circumstances the disease is gaining ground yearly.

CANKER (*Phytophthora Faberi*, Maubl.).

GRENADA. General but not severe.

ST. LUCIA. Generally distributed and should be regarded more seriously on some estates.

DOMINICA. Generally distributed.

BLACK ROT OF PODS (*Phytophthora Faberi*).

GRENADA. General but not severe

ST. LUCIA. Generally present and severe in certain localities.

DOMINICA. Generally distributed; found on trees suffering from canker.

BROWN ROT OF PODS (*Lasiodiplodia Theobromae*, Griff. et Maubl.).

GRENADA. Generally distributed but not severe.

ST. LUCIA. Generally distributed but no severe case reported by planters. Considerable losses often result from this disease which might in great measure be prevented if cacao husks were regularly buried instead of being scattered under the trees as is too commonly the practice.

DOMINICA. Commonly met with but to no great extent.

DIE-BACK AND STEM DISEASE (*Lasiodiplodia Theobromae*).

GRENADA. Generally distributed but not severe.

ST. LUCIA. A fair amount was met with, especially in exposed situations.

PINK DISEASE (*Corticium salmonicolor*, B. et Br.).

ST. LUCIA. None recorded or seen by any agricultural officer. In consequence of a statement as to its prevalence made at a meeting of the Legislative Council special enquiries were made with negative results.

LIMES AND OTHER CITRUS TREES.

BLACK ROOT DISEASE (*Rosellinia Pepo*, Pat., and *R. bunodes*, Sacc.).

DOMINICA. With the full information which is now within the reach of the planter relative to this disease steps are being taken to combat it in the majority of cases. The extra work involved in clearing up the damage to estates due to the hurricane will, it is feared, somewhat retard this action.

RED ROOT DISEASE (*Sphaerostilbe* sp.).

DOMINICA. An outbreak of this disease in a totally new district was reported during the year. It was associated with imperfect drainage. Vigorous steps are likely to be taken in this instance to deal with the situation.

UNIDENTIFIED ROOT OR COLLAR DISEASES.

GRENADA. Several trees on a heavily mulched experimental plot have died from a crown rot of which the specific cause has not as yet been determined.

ST. LUCIA. Gumming of the collar has been noticed in the case of trees in insufficiently drained fields.

DIE-BACK.

MONTSERRAT. In one 6-acre field, kept particularly under observation, where die-back had commenced previous to 1915, the decline has steadily continued during 1915 and 1916, both years of ample rainfall.

COCO-NUTS.

BUD ROT.

GRENADA. Suspected cases observed.

ROOT DISEASE.

GRENADA. Two or three cases of apparent root disease were observed in young palms.

INDIAN CORN.

Rust is fairly general but no particular ill effects are reported. Smut occurs sporadically but is not serious. The root diseases of this crop have not been worked out; severe local damage from this cause is recorded from St. Vincent, and damage the extent of which is uncertain from Antigua and St. Kitts.

SEEDLING DISEASES.

GRENADA. There was the usual damping off of seedlings at the Botanic Gardens in wet weather.

ST. LUCIA. Losses from damping-off were very severe throughout the year.

DOMINICA. No difficulty was found in controlling the damping-off of seedlings, which made an appearance in practically every bed sown As the seedlings appear above the ground they are dusted with a mixture of sulphur and lime, and the treatment is repeated if necessary.

MONTSERRAT. Both the usual damping-off and a new Phytophthora disease of seedlings were prevalent late in 1916.

GROUND NUTS.

LEAF RUST (*Uredo arachidis*, Lagh.).

ST. VINCENT. Generally present and severe in places.

ST. LUCIA. Slight attacks.

MONTSERRAT. Markedly severe in 1916, and at the Experiment Station not so well controlled by Bordeaux as in the two preceding years The quality of the produce was adversely affected in some cases.

ONIONS.

BACTERIAL ROT.

ST. LUCIA. Slight attacks.

NEVIS. Occurred in nearly every plot, but more serious in damp localities.

VIRGIN ISLANDS. Caused some loss during the season, but did not appear to be severe.

GENERAL REMARKS.

MONTSERRAT. On many areas planted in September and October there was a partial failure due to an inability of the plants to form bulbs, for which no reason was apparent. There was too much rain in the months of October and November and too little in December.

FUNGI PARASITIC ON INSECTS.

ON SCALE INSECTS.

GRENADA. The common species occurred as usual.

ST. LUCIA. The usual fungus parasites on scale insects were very active throughout the year, which was favourable to their development.

DOMINICA. The activity of these fungi has a great influence in maintaining the healthy condition of established lime fields.

MONTSERRAT. An undescribed species of Empusa was met with on green scale.

ANTIGUA. Parasitic fungi were fairly common during or after a wet period.

ON OTHER INSECTS.

GRENADA. The green muscardine (*Metarrhizium anisopliae*) was recorded on froghopper, and *Sporotrichum globuliferum.* on cacao thrips.

ST. VINCENT. A species of Isaria was found on a mole-cricket.

PHANEROGAMIC PARASITES.

LOVE VINE.

GRENADA. What appears to be a fungus disease of love vine is fairly common and seems to effect a useful measure of control.

ST. VINCENT. Cuscuta and Cassytha are abundant on hedges and wayside plants.

ST. LUCIA. Generally present on wild bushes and occurs on Hibiscus in some gardens.

DOMINICA. More generally distributed than it was at one time thought to be. No steps have been taken to control this serious pest in a methodical manner.

ANTIGUA. Increasing in one locality.

ST. KITTS. Increasing, especially in certain districts, but does not affect field crops.

NEVIS. Occurred to a considerable extent on hedges in some parts of the island.

VIRGIN ISLANDS. Very abundant after the cyclone. Probably theheavy rains of October and November favoured its development.

MISTLETOE.

GRENADA. Generally distributed but not abundant.

ST. LUCIA. Quite a serious pest on some lime estates.

DOMINICA. Generally prevalent. In the early part of the year more attention was given to this pest than has been the case for several seasons. What is required is continued effort over a number of years.

VIRGIN ISLANDS. Prevalent during the year, a favourite host plant being the avocado pear tree.

REMARKS ON ANY OTHER PLANT DISEASES.

DOMINICA. *Rosellinia* sp. was recorded attacking Para rubber and Gliricidia.

MONTSERRAT. An experimental plot of Hawaiian papaws was destroyed by a stem disease. The local type proved much more resistant.

SUMMARY OF DISTRIBUTION.

The following table is intended to show the status and distribution of the insects, fungi, and vegetable parasites attacking the principal crops. It has been drawn up from the information available at the Head Office of the Department, and has not been re-submitted to the officers in the various islands. While not claiming to be exact, it may be taken as affording a fair summary of the position during the year in question.

EXPLANATION OF SIGNS USED.

g = generally distributed.
G = generally distributed, severe.
l = local.
L = locally severe.
gL = Generally distributed, locally severe.
r = recorded present.
? = doubtful occurrence.
— = not known to occur in the island.
o = no record during the year.

A blank against the pests or diseases of any particular crop means that the crop is not grown at all or is not important in that island.

INSECT PESTS.

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
CACAO.									
Thrips	g L	g L	g	g					
Beetle	L	o	?						
Scale Insects and Mealy-Bugs..	r	o	o						
Termites	L								
Root Grubs				l					
Acrobat Ant	g								
COCO-NUTS.									
Weevil	r	o	o						
White Fly...	g	g	g	g					
Scale Insects	gL	g L	g	g		g		g	g L
CORN (INDIAN).									
Corn Ear Worm and Boll Worm	g	gL	g		g L	G	gL	g	
Hard Back Grubs ...	o	o	g			L	o	o	
Moth Borer	L								
Mole Cricket		g L							
Corn Leaf Hopper					l				
COTTON.									
Cotton Worm	o	g L			l	G	g	g	o
Boll Worm and Corn Ear Worm	o	o			g	g	o	o	
Cotton Stainers	o	G			l	L	g	G	g
Scale Insects	o	g			g	l	o	l	
Flower-bud Maggot	o	–			o	o	–	–	
Leaf-blister Mite...	o	g			l	g	g	G	G
Lachnopus								L	
Aphis									l
Cryptorhynchus Borer ..		l							
Thrips		l							
GREEN DRESSINGS.									
Leaf-eating Caterpillars ...	L	gL	g		L	o	g	o	
GROUND NUTS.									
Green Bug	o	g L	o				o	–	
Mealy-Bug	o	o	l				o	–	
Leaf-eating Caterpillars ...	o	o	o		l		o	–	

INSECT PESTS.—(*Concluded.*)

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
LIMES AND OTHER CITRUS TREES									
Scale Insects	g		g	g L	l	g		g L	
Bark Borer	—	o	g L	l	l	?		o	
Twig Borer	—	o	?	r	o	o		o	
Root Borer Grubs (*Diaprepes* spp.)	—		l	r	g	L		o	
Bagworm					l				
Diaprepes spp. (Adults)... ...	L				g				g L
Mole-Cricket			L						
ONIONS.									
Caterpillars		o		o	l	g		L	g L
Thrips		o			l	L		l	g L
Lachnosterna grubs						l			
SUGAR-CANE.									
Moth Borer	o	g L	g		l	g	g	g	
Weevil Borer	o	o	o			g	o	o	
Root Borers (*Diaprepes* spp.) ...	o	g	g			l	g L	g	g
Cane Fly	o	o	—				o		
Termites	o	o	o			l	l		
Hard Back Grubs (*Lachnosterna*)	o	o	o			L		g	
Froghopper	g L								
Grasshoppers							g L	r	
Mealy-Bug						g			
SWEET POTATOES.									
Caterpillars	o	o	l		o	g	o	o	
Scarabee	o	g	o		l	l	o	g	
Thrips	?	o	o			o	o	o	
Red Spider	g	g	l			o	o	o	
Slugs	L								
Sylepta helcitalis					l				
YAMS									
Scale Insects	o	o	o			g	o	g	

DISEASES.

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
CACAO.									
Root Disease	g L	o	g	g L					
Canker	g	o	g	g					
Black Pod Rot	g	o	g	g					
Brown Pod Rot	g	o	g	g					
Die-back and Stem Disease ...	g	o	g	g					
Pink Disease	o	–	o	o					
Thread Blight	o	–	–	o					
Horse-hair Blight	o	–	–	o					
COCO-NUTS.									
Root Disease	?	–	–			–		o	–
Bud Rot	?	o	–	–		–		o	–
Leaf Disease	o	o	o	o		o		o	o
CORN (INDIAN).									
Rust	o	l	g			r	o	o	
Smut	o	l	–			o	l	l	
Root Disease	–	L	–			g	l	o	
COTTON.									
Anthracnose		?			?	?	?	?	o
West Indian Leaf Mildew ...		g			g	g	g	g	o
Bacterial Boll Disease		G			g	o	g L	g	o
Angular Leaf Spot		G			g	o	g	g	o
Black Arm		g			g	o	o	r	o
Internal Boll Disease		G			L	l	r	g	o
Loggerhead Disease		–			–	–	o	o	o
Curly-leaf Disease		–			o	o	o	o	o
Phytophthora Soft Rot		L			L	o	o	o	o
GROUND NUTS.									
Root Disease		o	o		o		o		
Leaf Rust...		g L	l		G		o		
Leaf Spot...		g	o		o		o		
GUINEA CORN AND IMPHEE.									
Rusts					g			g	
Smut					o			o	
Root Disease					o			l	

DISEASES.—(*Concluded.*)

	Grenada.	St. Vincent.	St. Lucia.	Dominica.	Montserrat.	Antigua.	St. Kitts.	Nevis.	Virgin Islands.
LIMES AND OTHER CITRUS TREES.									
Black Root Disease	–		–	L	–				
Red Root Disease	–		–	L	–				
Pink Disease	–		–	l	–				
ONIONS.									
Bacterial Rot			l	o	o	o	o	gL	l
SUGAR-CANE.									
Root Disease	r	o	l			gL	l	g	l
Rind Fungus	o	o	l			g	o	o	o
Red Rot	o	o				o	o	o	o
Pine-apple Disease	o	o	–			o	o	o	o
SWEET POTATOES.									
Root Disease	–		–			g	o	o	
White Rust	o		o			o	o	o	
YAMS.									
Tuber Disease						o			
Wilt Disease						o			
PHANEROGAMIC PARASITES.									
Love Vine	g	g	g	L		l	l	l	g
Mistletoe	g	g	L	gL					g

THE LIMING OF SOILS.

BY SIR FRANCIS WATTS, K.C.M.G., D.Sc., F.I.C., F.C.S.,

Imperial Commissioner of Agriculture for the West Indies.

The use of lime as a means of ameliorating the condition of soil is well known, and one which is practised in a somewhat intermittent manner by West Indian planters. Interest has recently been aroused in this matter amongst local agricultural officers by the appearance of an important paper, entitled 'Studies on the Lime Requirements of certain Soils', by Messrs. H. B. Hutchinson and K. MacLennan, in the *Journal of Agricultural Science* (Vol. VII, p. 75, March 1915), in which two methods of investigation or analysis are described : (a) for determining the amount of lime (CaO) necessary to induce partial sterilization, and (b) for determining the amount of lime (CaO) or chalk ($CaCO_3$) required for soil neutralization. The former of these methods has been discussed by Dr. H. A. Tempany in a recent issue of this Journal (Vol. XVI, p. 145), to which reference may be made. The latter process consists in ascertaining how much bicarbonate of lime is neutralized by a known weight of soil, the amount so found being regarded as the quantity necessary to neutralize the soil acidity.

The method, which is simple, is thus described by the authors. For a determination of acidity, or lime requirement, 10-20 grams of the soil are placed in a bottle of 500-1,000 c.c. capacity, together with 200-300 c.c. of approximately N/50 solution of calcium bicarbonate, and the air in the bottle is displaced by a current of carbon dioxide in order to insure against possible precipitation of the calcium carbonate during the period of determination. The bottle is then placed in a shaking machine for three hours (occasional shaking by hand at intervals of twenty minutes gives identical results) after which time it is opened, the liquid is filtered, and a portion of the filtrate equal to half the original amount of the bicarbonate solution is titrated with N/10 acid, using methyl orange as an indicator. The difference between this final titration and that of the initial solution represents the amount of calcium carbonate absorbed, each cubic centimetre of N/10 acid being equal to 5 milligrammes of calcium carbonate.

This method is attractive in that it imitates somewhat closely what may be regarded as the process that may be expected to take place in the field when dressings of lime or of calcium carbonate are applied to the land.

Hutchinson and MacLennan recognized that the strength of the bicarbonate solution regulates the amount of absorption with any given soil, and it appears important that, for the reaction to approach completion within the prescribed period, the concentration of the initial solution should not be much below N/50 strength. Other workers have shown that the amount of bicarbonate absorbed varies with the amount of reacting base in contact with the soil ; it is necessary, therefore,

in order to obtain comparable results, to adhere to an arbitrary method of procedure, which should be stated when results are reported. L. P. Howard, who has investigated this aspect of the question, states (*Journal of the Association of Official Agricultural Chemists*, Vol. III, p. 144) that he believes it to be doubtful whether an absolute method can be evolved based on the principle of allowing a certain indefinite amount of reacting base to be in contact with the soil at the end of the reaction, and that he is investigating in order to ascertain whether a workable method can be devised, so that at the end of the reaction no excess of base remains in contact with the soil.

It may be well to mention a process which is much used, particularly in America, for determining soil acidity. This is the Veitch method, which is thus described by Hutchinson and MacLennan. Three lots of soil, each of 10 grams, are weighed into platinum basins, and about 50 c.c. of water added; three different volumes, say, 10, 20, and 30 c.c. of standard calcium hydroxide solution are added, and the basins are placed immediately on a water bath and their contents evaporated to dryness. With the aid of 100 c.c. of distilled water the soils are then transferred to Jena glass flasks, and allowed to stand overnight; the reaction of about 50 c.c. of the filtered liquid is tested by boiling phenolphthalein, the volume being reduced by boiling, if necessary, to 5 c.c. The three quantities of lime-water taken will generally suffice for orientation—one of the quantities being too small and the others too large for exact neutralization, or vice versa. Within the limits thus set by the trial determination other tests are made; where the amounts of lime-water vary by no more than 2 c.c., the appropriate requirement may thus be obtained. In order to obtain concordant results strict adherence to prescribed directions is essential.

With careful observation of the necessary restrictions, Hutchinson and MacLennan obtained moderately close agreement between the results of their method and those of the Veitch method. It may be pointed out, however, that other workers have found want of agreement between the methods, possibly on account of neglect to observe strictly the prescribed conditions.

The simplicity and apparent rationality of the Hutchinson-MacLennan method commend it for use in West Indian laboratories, and it is probable that the reactions of soils will be somewhat widely ascertained by this method in the near future.

Some results have already been reported. Mr. R. E. Kelsick has determined the reactions of some of the soils of St. Kitts, with the results given in the following table.

It will be noted that in three cases out of twelve, namely Nos. 1, 6, and 7, no lime is required to neutralize these soils. In the case of No. 1 crops are reported to grow well, but only moderately in the case of Nos. 6 and 7. One of these soils contained ·136 per cent. of carbonate of lime, the other two ·056 and ·060 per cent., respectively. In all the instances the amount of carbonate of lime, calculated from the evolved carbon dioxide, is very small.

Number.	$CaCO_3$ present in 100 of soil.	$CaCO_3$ requirement, H. & MacL. method, on 100 soil.	Equivalent lb. $CaCO_3$ required per acre of 3,000,000 lb.	Condition of sugar-cane crop.
1	·028	·060	1,800	Fair condition.
2	·076	·020	600	" "
3	·064	·040	1,200	" "
4	·136	nil	nil	Crops do very well.
5	·044	·020	600	Very poor, improved by liming.
6	·056	nil	nil	Moderate.
7	·060	"	"	"
8	nil	·150	4,500	Very poor.
9	·008	·096	2,880	" "
10	nil	·212	6,360	" "
11	·060	·019	570	Fair condition.
12	·076	·018	540	" "
13	?	·060	1,800	Very poor.
14	?	·088	2,640	" "

The principal crop grown upon these soils is sugar-cane. In one instance, No. 4, the crop is said to grow well; in five instances, Nos. 1, 2, 3, 11 and 12, the crops produced are reported as fair; in two instances as moderate; and in four, as poor. The evidence as to the relationship between the lime requirement as determined by the Hutchinson-MacLennan method and the growth of the crop of sugar-canes is, so far, quite incomplete, and much more work is needed before any sound conclusions can be drawn. Moreover, there may be a suspicion that in the investigation as conducted so far in St. Kitts, there has been a tendency to examine areas producing but moderate crops or poor ones; there is only one instance investigated where good crops are reported to be grown.

Information relating to a further series of right determination has been received since the foregoing was written; the data are as follows:—

Number. $CaCO_3$	$CaCO_3$ present in 100 of soil.	$CaCO_3$ requirement, H. & MacL. method, 100 of soil.	Equivalent lb. $CaCO_3$ required per acre of 3,000,000 lb.
15	nil	0·116	3,480
16	0·023	0·096	2,880
17	0·033	0·080	2,400
18	0·040	0·180	5,400
19	0·030	0·180	5,400
20	0·020	0·120	3,600
21	0·009	0·093	2,790
22	0·287	nil	nil

Samples 15 to 21 were taken from different fields on a large sugar plantation

Sample 22 was taken from the Botanic Station.

A limited but interesting amount of work has been done along similar lines in Dominica by Mr. G. A. Jones, Assistant Curator and Assistant Chemist in the Agricultural Department of that Presidency : his results are as follows :—

Locality	$CaCO_3$ requirement H. & MacL method of 100 soil.	Equivalent lb. $CaCO_3$ required per acre of 3,000,000 lb.	Remarks.
1 Cacao Expt Station	·037	1,110	Plot mulched with grass and leaves for seventeen years.
2 ,, ,,	·025	750	No manure applied for seventeen years.
3 Lime Expt. Station	·175	5,250	Soil containing 47 per cent. of silt and clay.
4 Lasoye	·082	1,860	Limes grown successfully for twenty years.
5 ,,	·015	450	Heavy soil, recently drained.
6 ,,	·295	8,850	Reclaimed swamp, surface soil well drained. Most luxuriant growth of lime trees.
7 ,,	·120	3,600	Reclaimed swamp: grew a heavy crop of sugar-cane in 1915.
8 Leeward Coast	·062	1,860	Grew well developed lime trees, recently infested with Sphaerostilbe root disease.
9 'Interior'	·792	23,760	Soil of unfelled forest, lying on sheet rock.
10 ,,	·737	22,110	Similar soil now in cultivation ; poor growth of limes.
11	·555	16,650	Deep soils cleared from forest during last ten to fifteen years. Typical of a large area of 'Interior' soils. Limes grown successfully, and, in the case of 14 and 15, most luxuriantly.
12	·605	18,150	
13	·432	13,050	
14	·419	12,570	
15	·400	12,000	

The smallest lime requirement, as indicated by the Hutchinson-MacLennan method, is met with in the soils of the cacao experiment plots at the Botanic Station, and it is curious to note that the plot which has received no manure for seventeen years has the smallest lime requirement. The area, No. 1, manured with grass and leaves, has produced very good crops of cacao for a number of years past, notwithstanding its apparent large lime requirement.

The Lasoye district referred to is situated on the north-east coast; it has long been cleared of forest, and much of it was formerly under cultivation in sugar-cane.

It is instructive to note that good crops are produced on these soils.

Perhaps the most interesting and instructive information is that furnished in connexion with the soils of the 'Interior', that is, of the central part of the island, which until recently was covered with forest, and which is being steadily cleared, chiefly for the cultivation of lime trees.

The first two samples referred to in the table as coming from this district are of soil overlying sheet rock, one from the uncleared forest, the other from an area planted with lime trees. In the latter instance it is reported that the growth is poor: this, however, would appear to be due rather to the presence of the sheet rock than to soil acidity, particularly in view of the conditions observed in other plots in this group. Cases Nos. 10, 11, 12, 13, and 14 are of much interest; they indicate that limes will grow well on forest soils showing a high lime requirement.

It is clear from the results put forward that in the case of limes growing upon soils recently cleared from forest, there is no connexion between the crop and the indicated lime requirement; limes are growing luxuriantly and are bearing large crops on soils that are to be regarded as distinctly acid when judged by the Hutchinson-MacLennan method.

It is to be regretted that no determinations were made in the course of this investigation in Dominica of the amount of carbonate in these soils: there is, however, some evidence on this point which may perhaps be cited. In an examination into the physical and chemical characters of the soils of Dominica made in 1902,* the amounts of carbonate present in twenty-three samples taken from various parts of the island were determined. These soils were classified as having a 'high' carbonate content when the amount of carbon dioxide evolved was equivalent to ·5 per cent., 'medium' when it was equivalent to between ·1 and ·5 per cent., and 'low' when it fell below ·1 per cent. There were five instances reported as 'low', sixteen as 'medium', and only one as 'high'. This latter was in the case of a sample taken from Middleham, a district then largely covered with forest. This soil contained 8·3 per cent. of carbon as organic matter, and no doubt would have shown a comparatively high acidity had it been examined by the Hutchinson-MacLennan method. Other samples taken in the 'Interior' from Sylvania, Corona, and

*Report on the Physical and Chemical Analyses of the Soils of Dominica, by Francis Watts, 1902.

Riversdale gave indications of ·400, ·480 and ·181, respectively, and were classed as having 'medium' amounts, though in two of these instances the amounts were fairly large. It may be concluded, therefore, that these forest soils showing a high lime requirement, contain appreciable quantities of carbonates. They are capable of producing good crops of limes.

Similarly, certain of the soils of St. Kitts show a large lime requirement by the Hutchinson-MacLennan method, yet they contain a certain amount of carbonate, and also give fair crops of sugar-cane and cotton.

We are thus confronted with a curious situation: the so-called acid soils contain carbonates, and neutralize or absorb further quantities of carbonate of lime. It would seem, therefore, either that the existing carbonate of the soil is protected from the soil acid, or that this acid is an extremely weak one, when it is difficult to understand its neutralizing the added carbonate; or else the absorption of the added carbonate of lime is not due to soil acidity but to some other cause.

The fact that the lime requirement of a soil, as determined by such methods as those of Hutchinson and McLennan or Veitch, shows considerable variation, according to the amount of lime added to a given quantity of soil in making the determination, would lead one to suspect that the phenomenon is not simply one of neutralization, or if it is due to neutralization, then to the neutralization in certain cases of extremely weak acids, such as silicic acid and the alumino-silicates and similar bodies, the end point of whose reaction with carbonate of lime or lime is not readily determined by means of phenolphthalein or methyl orange.

This aspect of the question has been examined by Mr. George J. Bouyoucos, and the results published in *Technical Bulletin*, No. 27, of the Michigan Agricultural College Experiment Station, under the title: 'The Freezing Point Method as a New Means of Determining the Nature of Acidity and Lime Requirement of Soils'. This investigator has employed the freezing point method of investigating the problem. He states: 'It was reasoned that if the soil contains a free soluble acid, this acid would possess a definite freezing point depression at a certain concentration. Upon titrating this with a base, such as $Ca(OH)_2$, a salt would be formed. This salt would probably possess a different freezing point depression from that of either of the reacting agents. The depression then should vary as more and more of the lime is added to the soil until the neutralization point is reached where the formation of the salt is completed, and then the direction of the depression should change. If, on the other hand, the soil does not contain a free soluble acid, but possesses an absorptive power for lime due to its unsaturated or unsatisfied silica compounds and organic matter, then the depression of the freezing point of the soil should remain the same as more and more lime is added, until these silicate compounds and organic matter are satisfied with the base, and then it should increase with further addition of $Ca(OH)_2$. Finally, if the soil is alkaline or already saturated with bases, then the depression should begin to rise immediately

upon adding a small amount of $Ca(OH)_2$ to the soil. Happily, all these *a priori* predictions were actually and experimentally realized in soils exactly as they are described above.'

Space precludes an extensive discussion of this paper. The results put forward are very striking, and appear to advance considerably our knowledge of the important questions connected with the lime requirements of soils. It must suffice to say here, that the freezing point of a mixture of soil and water is determined, and then the freezing point of the same soil and water, after the addition of successive known quantities of $Ca(OH)_2$ in the form of lime-water. The depressions of the freezing point are then plotted as a curve.

The results obtained show that three kinds of curve are met with: in the first place, the *acid curve*, in which the freezing point depression steadily increases as more and more lime is added, until a point is reached at which further additions of lime cause a diminution of the depression. The lime requirement of the soil is taken to be that which corresponds with the amount of lime added at the point where the depression is greatest.

The next is the *absorption curve*. In this the depression of the freezing point remains the same with successive additions of lime, until at last a point is reached where the depression diminishes. The lime requirement of the soil is indicated by the point at which the further addition of lime causes a change in the direction of the curve; that is to say, when the depression of the freezing point diminishes.

Finally, there is the *alkaline* or *no-lime requirement curve*. In this instance the depression of the freezing point begins to diminish with the first addition of lime, and progressively diminishes as more is added. Soils exhibiting this form of curve require no lime.

As the result of examining a large number of soils, Bouyoucos arrives at the conclusion that soils and soil constituents may be divided into two categories so far as their relation to lime is concerned, namely into mineral soils or mineral constituents, and peaty soils or peaty or organic constituents. He found that the mineral soils gave an absorption and not an acid curve, and that the peaty soils gave an acid curve, and he arrives at the following generalization: 'The acidity or lime requirement of soils might be ascribed almost entirely to insoluble hydrated silicic acid, acid alumino-silicates, silica, and organic soluble substances in the case of the mineral soils, and to organic soluble acids and humus substances, and organic insoluble acids and humus substances in the case of peats and mucks.'

In his general summary the following useful statement occurs: 'Since no mineral soil out of a great number tested gave an acid curve, but only an absorption curve, and inasmuch as the free acid and acid salt produced in these soils when they were treated with neutral salts, or acid and acid salts, were carried away by washing, and the soils then gave an absorption curve, the conclusion seems to be that the presence of soluble acids, or acid salts in the mineral soils under favourable natural conditions is only temporary, if ever present, and never permanent. The acidity or lime requirement of soils, therefore, seems to be due

mainly to the insoluble acids of the soil, the silicic acid, silica, acid alumino-silicates, and perhaps to the insoluble organic matter. There appears to be then practically no active acidity in the mineral soils, but only negative. Exceptions to these general statements are probably very few.

'In the peats and mucks, however, the formation of organic acids is probably quite rapid, and consequently these soils, as indicated by the data, may contain permanent active acidity as well as permanent negative acidity.'

It is stated that the freezing point method usually indicates a much higher lime requirement than the Veitch method. This investigator made no comparison with the Hutchinson-MacLennan method.

The author's remarks as to the agricultural application of this and other methods are worth quoting. He says: 'While the freezing point method probably indicates the true lime requirements of soils, no claim is made that it is necessary to add all that amount of lime to the soils; this point will ultimately have to be decided in the field, using the plant as the indicator. As previously intimated, probably no laboratory method, including the freezing point method, could ever be expected to designate definitely how much lime should be added to the soil. This is clearly obvious from the fact that the plant is used as an indicator to determine the effects of acidity and basicity upon its growth, and since it is found that different plants are affected differently by these qualities. All that a laboratory method might even be expected to do, at least from the practical standpoint, is to show the maximum lime requirement of the soils, and then apply the lime to these soils according to the requirements of the crops planted. This certainly appears to be the most rational and intelligent procedure. However, the experience of various observers goes to indicate that heavy applications of lime increase the growth of most crops very markedly, and these quantities are in accordance with those indicated by the freezing point method.'

These views as to the causes of the absorption of lime by soil are not incompatible with the presence in soils showing considerable 'lime requirement' of small amounts of carbonate of lime; they also dispose of the idea that such soils are acid or 'sour' in the ordinary sense.

It is probable that for the cultivation of the majority of West Indian crops the factor which is of great importance is the presence of even small amounts of carbonate of lime. Soils containing even small amounts, even although they may exhibit the power of absorbing lime in a considerable degree when tested by one or other of the methods for determining 'lime requirement', appear to be capable of producing good crops, as is seen in the cases referred to in relation to some of the St. Kitts and the Dominica soils. It would seem, therefore, that in the examination of soils great attention should be paid to the estimation of minute quantities of carbonate.

The soil conditions of several of the West Indian islands have been carefully studied, and analyses have been made in which this question of the amount of carbonate of lime, although often

exceedingly small, has had direct consideration. Reference may be made to the following papers in this Journal: 'The Soils of Montserrat', Vol. VI, p. 263, 'The Soils of Nevis', Vol. IX, p. 60, 'The Soils of Antigua', Vol. XV, p. 69: also to the 'Report on the Physical and Chemical Analyses of the Soils of Dominica, Watts, 1902,' and that on the 'Soils and Rocks of Grenada and Carriacou, Harrison, 1896.' The majority of the soils discussed in these papers are of volcanic origin, and contain but small quantities of carbonate of lime. In a few instances the amounts are exceedingly small. It is hoped that in the near future much more attention will be given to this aspect of the case, for it is felt that while the results of field experiments with crops are accumulating, planters may safely be advised to apply lime to those soils, such as those referred to above in the case of St. Kitts, where carbonate of lime appears to be entirely absent, or where the amount is exceedingly small, say, less than ·05 per cent.

As already noted, the correct method of ascertaining the lime requirement of any soil in relation to any particular crop is to conduct field experiments to ascertain the effect of dressings of lime in various forms, and in different quantities. Obviously there can be no definite uniform lime requirement of any particular soil, unless account is taken of the particular plant to be grown. It is well recognized that certain plants thrive well only when there are fairly large amounts of lime in the soil. Amongst agricultural crops, sainfoin and lucerne may be mentioned as lime-loving, while most, but not all leguminous crops thrive best on calcareous soils, as do many trees and weeds. A list is given in Hall's well-known book 'The Soil', p. 282, which it is unnecessary to repeat here. Unfortunately there are no similar lists available as regards West Indian plants, and it is desirable that information on this point should be accumulated.

On the other hand, there are many plants which prefer soils containing but very little carbonate of lime, such as lupins, serradella, and gorse; while there are very many which appear to be somewhat indifferent, growing as well on soils which contain a good deal of carbonate of lime as on those which contain relatively little. This character of indifference appears to be quite marked in the majority of the crops grown on a considerable scale in the West Indies. Thus it is seen that the sugar-cane grows equally well on the calcareous soils of Barbados, Antigua, and Guadeloupe, and on the non-calcareous ones of St. Kitts, Montserrat, Antigua, and the volcanic islands generally. The same appears to be true of most of the crops commonly grown, such as sweet potato, yam, cassava, arrowroot, various peas and beans, maize, and, in fact, the majority of West Indian crops. It is commonly recognized that both lime and cacao trees thrive on soils containing very small amounts of carbonate of lime, and in the many experiments that have been made in adding lime to the soil of cacao orchards, it has seldom resulted that the crop has been markedly increased, though doubtless there are many instances where the soil of cacao orchards contains such small quantities of carbonate of lime that the application of lime might be expected to prove beneficial. It would be well worth while to examine the soil of cacao orchards specifically as to their

carbonate of lime content, and to ascertain the effect of adding lime in cases where the deficiency is very pronounced. So far as the writer of this paper can recollect, there does not appear to be any instance of a cacao industry being carried on where the soil is distinctly calcareous.

The evidence obtained from Dominica and other West Indian islands shows that lime trees will flourish on soils containing remarkably small quantities of carbonate of lime; they do not appear to thrive so well on calcareous soils, though they do grow fairly well in Barbados and Carriacou on such soils. Probably they may be ranked amongst those plants which are indifferent in this respect.

It is clear, then, that regular and systematic experiments must be the basis of agricultural investigations on this subject. Field work must play even a more important part than laboratory work in this particular.

It is important to remember that lime has a relationship to soil condition somewhat independent of the immediate requirement of the plant. The presence of sufficient carbonate of lime to serve as a base is necessary for the process of nitrification. An excess of lime in the form of hydrate effects marked changes in the physical characters of heavy soils, flocculating them and rendering them more open and friable. Again, as Hutchinson and MacLennan have shown, the presence of an excess of lime, as hydrate, effects partial sterilization, so altering the micro flora of the soil that important changes in bacterial and other activities result, which may have great influence on the succeeding crops cultivated on land so treated. This latter aspect has already been discussed in this Journal (Vol. XVI. p. 145).

The subject is, it must be recognized, an extremely complex one, and one which cannot be dealt with by laboratory investigations alone. Nothing but careful field experiments carefully controlled by laboratory investigations can demonstrate what is required in agricultural practice in this particular. It is evident, therefore, that such experiments should be extensively conducted by the joint activities of planters and agricultural officers, and the results carefully recorded and studied, before the best practical methods for any district can be laid down. It is worse than useless to dogmatize from the agricultural practice of other countries.

MANURIAL EXPERIMENTS WITH CACAO IN DOMINICA.

BY JOSEPH JONES.

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The following review, by Mr. J. Jones, of the work in connexion with the manurial experiments with cacao in Dominica, is taken from the Annual Report for 1916-17 of the Agricultural Department of that Presidency. Attention may be drawn to the statement made relative to the effect of the manurial treatment given during the first two years to plots Nos. 2 to 5, and the probable effect of this treatment on the yields of these plots in the third year, when the practice of weighing the crop was introduced, as compared with the yield of the no-manure plot, which had been the subject of comment in the *West Indian Bulletin*, Vol. XVI, p. 125. [ED. *W.I.B.*

MANURIAL EXPERIMENTS WITH CACAO.

The customary review of the results obtained in the manurial experiments with cacao conducted by the Agricultural Department in Dominica is now given.

A change in the method of presenting the report was made last year, and the method then adopted is again used. Nine of the eleven plots have been running for a sufficient length of time to draw definite conclusions therefrom, whilst the remaining two, started in 1913 14, are not strictly comparable, and are therefore discussed separately.

The first seven plots are situated on level ground and occupy approximately 2 acres. The soil is moderately even in character, especially that of plots 1, 2, 3, 6 and 7. Plots 4 and 5, on a lower level, are rather heavier, plot 4 being distinctly so.

Plots 8 and 9 are situated on a steep hillside, a situation typical of many acres of cultivation in Dominica.

The physical and chemical nature of the soils of the plots have been ascertained at the Government Laboratory, Antigua, and may be seen on reference to the *West Indian Bulletin* (Vol. IV, pp. 81-119).

It is here necessary to make a correction in the published figures of the last few years. In a paper recently published* on the significance of the results obtained in these experiments, the writer, Mr. W. R. Dunlop, makes the following statement :—

'In previous statements of the results of these experiments however, one important point has not been taken into account. It will be observed that the yield of the control plot began some 300 ℔. of cured cacao per acre below the plots which were to receive treatment : . . . . allowance should have been made for this constant difference.'

* *West Indian Bulletin* Vol. XVI, pp. 121-6.

On referring to previous progress reports of this Department, it will be ascertained that in the year 1900-1, the Hon. (now Sir) Francis Watts laid out a certain scheme of manurial treatment, which after slight modification was adopted in that year. The manures were applied in May-June of the same year for the first time, and the same manures have been used annually without a break since that date.

In the following year (Progress Report, 1901-2 p. 5), the following report on these plots appeared :—

'The cacao manurial plots failed to show any improvement over the control plot during the year. This is attributable to two very dry years, the rainfall in which was 33·31 inches and 23·95 inches, respectively, below the average. During the present period the rainfall has been normal, but badly distributed, nearly 50 inches falling in June, July, and August. The experiment will be continued, and the result of the application of special manures, if any, noted under normal climatic conditions.

'What strikes one most in dealing with fields made up of various strains, is that certain kinds of cacao usually bear well, while other trees exist that year after year bear little or nothing. This shows the importance of selecting pods for seed from prolific strains only. This has been done largely in Dominica for the past nine years. All the plants and pods distributed are carefully selected, and in quality and bearing powers, Dominica cacao should show a great improvement in the future.'

For the first two years the yields of the plots were not actually weighed, as it was then thought possible to estimate the results sufficiently accurately by the appearance of the trees and the crops thereon. After two years of manuring the plots failed to show any visible improvement over the control plot.

During 1902 3, after the third application of manures, it was decided to weigh the yields from each plot separately, and the figures were published.

The conclusion of the writer referred to above, as to the natural yield of the control plot being lower, cannot be accepted as definite. The increase of some 300 lb. of cured cacao per acre shown by all the plots over the control plot in 1902-3, may quite easily have been due to the two applications of manure they had received, and not to the supposed smaller 'natural yield' of the control plot. As reference to these reports show, the control plot was in no way inferior to the other plots at the outset of the experiment.

It is regretted that these facts were omitted from previous recent reports; the omission has led to a certain amount of confusion.

The first five plots were thus started in the year 1900-1, and the crops were first weighed in 1902-3. Similar treatment has been accorded to each plot in every succeeding year, so that at the present time the condition of each represents the accumulated results of seventeen years' continuous treatment on the same lines. The remaining four plots were started eight years later, and each plot has thus obtained identical treatment for ten years.

TABLE I.

AREA OF PLOTS UNDER EXPERIMENT, 1916-17.

The following table shows the number of trees per plot and per acre at the present time, the area of each plot, the manurial treatment received, and the year of the first application of the manure:—

Number.	Letter on station plan.	No of trees per plot, 1917. Bearing.	Non-bearing.	Area of plots, in acres.	Manurial treatment.	Year of first application.
1	C	54	15	0·28	No manure.	1900-1
2	A	60	6	0·29	Basic slag. 4 cwt. per acre. Sulphate of potash. 1½ „ „ „	„ „
3	B	66	5	0·36	Dried blood, 1 „ „ „	„
4	E	42	6	0·29	Basic slag, 1 „ „ „ Dried blood, 1 „ „ „ Sulphate of potash, 1½ „ „ „	„ „ „
5	D	49	4	0·37	Mulched with grass and leaves, 5 tons per acre.	„
6	F	19	6	0·25	Mulched with grass and leaves, 4 tons per acre.	1907
7	G	50	3	0·25	Cotton-seed meal, 660 lb. per acre.	„
8	H	86	2	0·114	No manure.	„
9	I	88	1	0·373	Mulched with grass and leaves, 5 tons per acre.	„
10	K	106	...	0·1	Mulched with grass and leaves. 2½ tons per acre. Lime. 5 cwt. „ „	1913
11	L	95	..	0·25	Calcium cyanamide (Nitrolim), 2½ cwt. per acre.	„

Some years ago the plan was adopted of planting on each plot a sufficient number of trees to cover the ground, and the figure given represents the number of bearing trees in each plot at the present time. In several plots a number of trees have

recently died, especially in the control plot 1, there being no fewer than fifteen non-bearing trees in this plot at the present time. The continued fluctuation in the number of trees renders the figure for the yield per tree very uncertain, and this has in consequence been omitted from the results for the season now under review.

The plots have received the same manurial dressings as in previous years. The method of application consists of raking away the leafage in a circle round each tree, applying the manure in the space thus uncovered, and then raking back the leaves over the manure. In those plots receiving both basic phosphate and dried blood, an interval of several weeks is allowed between the application of the two manures. The mulch after being carefully weighed is scattered evenly over the surface of the plot. The material of which the mulch is composed is of two types, varying widely in their chemical composition. To the mulched plots 5 and 6, varying quantities of mulch composed largely of fallen leaves and pods of the Saman tree (*Pithecolobium Saman*) are used; for plots 9 and 10 no Saman tree material is utilized, but in this case the fallen leaves of the West Indian mahogany tree (*Swietenia Mahagoni*) supply the mulching material. The manures and the mulch are applied once a year. These are the sources of coarse organic matter which are available in an experiment station of this nature. Similar results would in all probability be obtained by the use of many other forms of organic matter. As an appendix to last year's report, there was given the analysis of a large number of materials which could be utilized equally well. Several of these are under experiment in this Station, and reliable information as to the quantity which can be produced, and the cost of production will, we hope, be soon available. The value of several of these manures, such as pen manure, sheep manure, etc., is well known and appreciated by planters.

No forking has been performed in any of the plots since the inception of the experiments, the only cultural operations undertaken beyond the application of the manures being the usual ones connected with the pruning of trees, and sanitation of the orchard.

The yields of cacao recorded each year are for periods of twelve months terminating on June 30. This date is chosen because there is no cacao being gathered at that time. Other dates possess the disadvantages that, owing to the fluctuations in the spring or carême crop, it may happen that two such crops are included in one year—a late crop of one year, and an early crop of the succeeding year; while on other occasions there may be no carême crop in the year under review. Such fluctuations disturb and confuse the records, hence the results are made to refer to the crop year extending from July 1 to June 30. This mode of reckoning is recommended for adoption as a basis of records in connexion with West Indian cacao crops.

Rainfall.

The annual rainfall for each year since the inception of the experiments is given below. In accordance with the matter in the previous paragraph, the figures are given for twelve months commencing on July 1 of one year and ending on June 30 of the next.

Period.		Year.	Inches
Twelve months ending June 30.	...	1903	72·46
" " " " "	...	1904	93·02
" " " " "	...	1905	70·13
" " " " "	...	1906	74·60
" " " " "	..	1907	69·02
" " " " "	...	1908	67·08
" " " " "	...	1909	69·47
" " " " "	...	1910	94·90
" " " " "	...	1911	89·71
" " " " "	...	1912	80·54
" " " " "	...	1913	64·76
" " " " "	...	1914	71·60
" " " " "	...	1915	80·00
" " " " "	...	1916	94·10
" " " " "	...	1917	93·71

The following table shows the yields in the year under review, together with those from the plots in each year since the systematic record of the returns was first undertaken.

The yields of the past year are shown in the bottom line of the table. This method enables the progress of each of the plots to be seen at a glance. The yields are given in terms of pounds of wet cacao per plot and per acre, and cured cacao pounds per acre. In calculating the yield of cured cacao per acre, the assumption is made that 100 lb. of wet cacao will yield 42 lb. of cured cacao.

Table II.

MAIN SERIES.

Yield for seventeen years, 1900-17.

Year.	Plot 1. No manure.		Plot 2. Phosphate and potash.		Plot 3. Dried blood.		Plot 4. Dried blood, phosphate and potash.		Plot 5. Mulched with grass and leaves.	
	Per plot.	Per acre	Per plot.	Per acre.	Per plot.	Per acre.	Per plot.	Per acre.	Per plot.	Per acre.
1900-2	No	reco	rds	were	kept.					
1902-3										
Wet cacao ...	759	2,711	1,063	3,666	1,281	3,588	1,104	3,807	1,145	3,095
Cured cacao	...	1,138	...	1,540	...	1,494	...	1,599	...	1,300
1903 4.										
Wet cacao .	548	1,956	808	2,786	970	2,694	738	2,545	962	2,600
Cured cacao	...	822	...	1,170	...	1,131	...	1,069	...	1,092
1904-5.										
Wet cacao	673	2,403	814	2,801	970	2,694	979	3,376	1,279	3,457
Cured cacao	...	1,009	..	1,179	...	1,131	...	1,418	..	1,450
1905-6.										
Wet cacao ...	748	2,672	763	2,631	1,056	2,933	1,040	3,586	1,519	4,105
Cured cacao	..	1,122	.	1,105	...	1,232	...	1,506	...	1,724
1906-7.										
Wet cacao ...	730	2,607	887	3,059	972	2,700	1,009	3,479	1,536	4,151
Cured cacao	..	1,095	...	1,285	..	1,134	...	1,461	..	1,743
1907-8.										
Wet cacao ..	903	3,225	1,160	4,000	1,381	3,836	1,180	4,069	1,773	4,792
Cured cacao	..	1,354	..	1,680	...	1,611	...	1,709	...	2,012
1908-9.										
Wet cacao .	978	3,492	1,205	4,155	1,377	3,825	1,344	4,634	1,777	4,803
Cured cacao	...	1,467	...	1,715	...	1,607	...	1,946	..	2,017
1909-10.										
Wet cacao ...	848	3,029	963	3,321	1,167	3,241	1,267	4,369	1,822	4,924
Cured cacao	...	1,272	...	1,395	...	1,361	...	1,835	...	2,068
1910 11.										
Wet cacao ...	859	3,067	1,097	3,783	1,289	3,581	1,297	4,473	1,890	5,107
Cured cacao	...	1,288	...	1,589	...	1,504	...	1,879	..	2,145
1911-12.										
Wet cacao ..	804	2,871	1,012	3,490	1,272	3,533	1,272	4,387	1,721	4,651
Cured cacao	...	1,206	...	1,466	...	1,484	..	1,842	...	1,953
1912-13.										
Wet cacao ..	892	3,186	1,088	3,752	1,512	4,200	1,314	4,531	2,001	5,408
Cured cacao	...	1,338	...	1,576	...	1,764	...	1,903	...	2,271
1913-14.										
Wet cacao ...	678	2,422	885	3,050	1,133	3,147	1,104	3,807	1,509	4,078
Cured cacao	...	1,017	...	1,281	...	1,322	...	1,599	...	1,713
1914-15.										
Wet cacao ...	779	2,782	1,049	3,617	1,366	3,794	1,133	3,907	1,715	4,635
Cured cacao	...	1,168	...	1,519	...	1,593	...	1,641	...	1,947
1915-16.										
Wet cacao ...	715	2,554	1,110	3,827	1,298	3,607	1,069	3,686	1,474	3,984
Cured cacao	...	1,073	...	1,607	...	1,514	...	1,548	...	1,673
1916-17.										
Wet cacao ..	941	3,361	1,285	4,431	1,497	4,158	1,486	5,124	1,772	4,789
Cured cacao	...	1,412	...	1,861	...	1,746	...	2,152	...	2,011

Table III.

ADDITIONAL SERIES.

Yield for ten years, 1907-17.

Year.	Plot 6.		Plot 7.		Plot 8.		Plot 9.		Plot 10.		Plot 11.	
	Mulched with grass and leaves.		Cotton-seed meal.		No manure.		Mulched with grass and leaves.		Mulched with grass and leaves.		Calcium cyanamide (nitrolim).	
	Per plot.	Per acre.	Per plot.	Per acre.	Per plot.	Per acre.	Per plot.	Per acre.	Per plot.	Per acre.	Per plot.	Per acre.
1907-8.												
Wet cacao ..	881	3,524	1,019	4,076	882	2,130	1,053	2,823				
Cured cacao	...	1,480	...	1,712	..	895	...	1,186				
1908-9.												
Wet cacao ...	1,119	4,476	1.060	4,240	957	2,311	1,214	3,255				
Cured cacao	...	1.880	...	1,781	...	971	...	1.367				
1909-10.												
Wet cacao ..	1,242	4,969	10,39	4,156	965	2,331	1,352	3,625				
Cured cacao	..	2,087	..	1,746	..	979	...	1,523				
1910-11.												
Wet cacao ..	1,225	4,900	1,006	1,021	977	2,360	1,897	5,086				
Cured cacao	...	2,058	..	1,690	..	991	..	2,136				
1911-12.												
Wet cacao ..	1,070	4,280	92	3,692	924	2,232	1,669	4,476				
Cured cacao	...	1,798		1,519	...	937	..	1,879				
1912-13.												
Wet cacao ...	1,377	5,508	1,207	4,828	845	2,011	1,674	4,487				
Cured cacao	..	2,313	.	2,028	...	857	...	1,885				
1913-14.												
Wet cacao ...	1,300	5,200	924	3,696	767	1,853	1,548	4,150	667	1,667	609	2,436
Cured cacao	...	2,184		1,552	...	778	...	1,743	..	700	..	1,023
1914-15.												
Wet cacao ..	1,529	6.116	1,229	4,916	947	22,87	1,750	4,692	899	2.242	782	3,128
Cured cacao	..	2.569	. .	2,065	...	960	. .	1,971	..	942	...	1,314
1915-16.												
Wet cacao ..	1,380	5,520	977	3,908	811	1,966	1,132	3,839	1,024	2,560	795	3,180
Cured cacao	.	2,318		1,641	...	825	..	1,612	..	1,075	.	1,336
1916-17.												
Wet cacao ...	1.380	5,520	1,118	1,472	1,124	2,715	1,563	1,190	1,231	5,085	862	3,448
Cured cacao	..	2,518	. .	1,878	...	1,140	...	1,760	. .	1,296	...	1,418

Table IV.

Average Annual Return for fifteen years.

The following supplementary table gives the average annual return of wet and dried cacao in pounds for fifteen years in the case of the first five plots, and for nine years in the case of plots 6 to 9. The last column shows the percentage increase of each plot over the no-manure plot :—

No.	Manurial treatment.	Wet cacao, per plot.	Wet cacao, per acre.	Cured cacao, per acre.	Increase over no-manure plot, per cent.
1	No manure	790	2.821	1,185	...
2	Phosphate and potash	1,013	3,493	1,467	23·8
3	Dried blood	1,236	3,433	1,442	21·7
4	Dried blood, phosphate and potash	1,156	3,986	1,674	41·3
5	Mulched with grass and leaves ...	1,590	4,297	1,805	52·3
6	Mulched with grass and leaves	1,250	5,000	2,100	77·2
7	Cotton-seed meal	1,050	4,200	1,764	18·8
8	No manure	920	2,222	933	.
9	Mulched with grass and leaves ...	1,515	4,062	1,706	82·8

The pecuniary aspect of the experiments is dealt with in the two following tables, in which are shown the gain from the application of the different manures both for the average return of the entire period during which the experiments have been conducted, and that for the year under review. In calculating the monetary gain, the value of cured cacao has, as in previous reports, been assumed at 6*d*. per lb. During the last two years the value of cacao has been very considerably higher than this, but at the same time the cost of the manures has risen, especially sulphate of potash. now practically unobtainable on a commercial scale.

Under these circumstances. it is thought best not to change the values, at least not until conditions are more settled.

In calculating the monetary gain resulting from the application of the various manures, the cost of collecting and applying the mulch to the various mulched plots has been assumed to be 80s. per acre. In practice at the Botanic Garden it is considerably less than this, since the collecting of the fallen leaves constitutes a part of the ordinary routine in the care of the grounds. It is estimated, however, that a mulch of the size

indicated could be obtained from the surrounding bush and applied under the conditions obtaining on a cacao estate in Dominica, for the sum mentioned. Further, under estate conditions in Dominica, sheep and pen manure can be made at a cost of under 20s. per ton, and this when applied to the cultivation would produce similar results to the mulch referred to above.

TABLE V.

Monetary gain from Manuring.

The following table shows the average monetary gain from manuring over the whole period of the experiments :—

Plot.	Average annual yield of cured cacao, per acre.	Gain in cured cacao over No manure.	Value per acre of increase over No manure at 6*d.* per lb. of cured cacao.		Cost of manuring per acre.		Net gain per acre by manuring.	
	lb.	lb.	s.	d.	s.	d.	s.	d.
1	1,185	...	...		...		...	
2	1,467	282	141	0	45	3	95	9
3	1,442	257	128	6	52	0	76	6
4	1,674	489	244	6	97	3	147	3
5	1,805	620	310	0	80	0	2[illegible]0	0
6	2,100	915	457	6	80	0	337	6
7	1,764	576	288	0	40	0	248	0
8	993	...	...		...		...	
9	1,706	773	386	6	80	0	306	0

The monetary gain for manuring during the year 1916-17 may be shown as follows:—

No.	Yield per acre of cured cacao, 1916-17.	Gain per acre over No manure.	Value per acre of increase over No manure at 6*d.* per lb. of cured cacao.	Cost of manure per acre.	Net gain per acre by manuring.
	lb.	lb.	s. d.	s. d.	s. d.
1	1,412	...	...	...	...
2	1,861	449	224 6	45 3	179 3
3	1,746	334	167 0	52 0	115 0
4	2,152	740	370 0	97 3	272 9
5	2,011	599	299 6	80 0	219 6
6	2,318	906	453 0	80 0	373 0
7	1,878	466	233 0	40 0	293 0
8	1,110	...	..	...	...
9	1,760	620	310 0	80 0	230 0

Comparison of Results.

The yield of the plots during the past year when compared with that of previous years gave satisfactory results. When compared with the results of the preceding year, which owing to unfavourable climatic conditions was not a good year, the increase looks abnormal, but when compared with the average yields of the whole period we find that all the plots show substantial increases.

The results obtained by this method are tabulated below:

No.	Average yield over whole period of experiment, in cured cacao, lb. per acre.	Yield for 1916-17 in cured cacao, lb. per acre.	Increase or decrease in lb. of cured cacao.	Increase in 1916-17 over whole period, per cent.
1	1,185	1,412	+227	19·1
2	1,467	1,861	+394	26·8
3	1,442	1,746	+304	21·1
4	1,674	2,152	+478	28·0
5	1,805	2,011	+206	11·3
6	2,100	2,318	+218	10·7
7	1,764	1,878	+114	6·4
8	933	1,140	+207	22·0
9	1,706	1,760	+ 54	3·1

During the past year a hurricane was experienced which accounts for the variation between the increased yields of the various plots.

Some of the plots suffered the loss of several trees, others were only badly shaken. From observations made it would appear probable that when fruit trees are seriously shaken the tendency is for them to flower profusely and produce an abundance of fruit. This is probably what has happened to the complete manure plot, which produced the highest yield on record for this crop, and 28 per cent. more than the average return over seventeen years.

The trees on this plot certainly do not look well, and one fears that in spite of this heavy crop, they are not in a satisfactory condition, and that in a few years a considerable falling off will be recorded.

Though the foliage of the trees on plot A (phosphates and potash) is scanty, the trees continue to bear well. Nevertheless phosphates and potash without nitrogen cannot be regarded as a satisfactory manure for cacao.

The cotton-seed meal plot again maintains its satisfactory condition as regards yield, and it is certainly a very sound manure to use. We would, however, recommend that for the best results a heavier application than 600 lb. per acre be given: 1,000 lb. per acre would probably be sufficient not only to give satisfactory crops but also to maintain the trees in a vigorous state of health.

Dried blood or some other form of organic matter of a similar nature can be recommended, though much better results are obtainable when the nitrogen of this manure is supplemented with phosphates and potash.

The chief feature of these experiments is, however, the way they have proved that, by maintaining the humus content of the soil by systematic applications of organic matter, it is unnecessary to resort to the use of artificial manures. The high yields recorded in previous reports are again reached on these plots during the year.

With a view of ascertaining the least amount of mulch necessary to produce satisfactory results, a plot was started in 1913-14 which receives only 2½ tons per acre as against the higher amounts (5 tons and 1 tons) used on the other mulched plots.

In three years the output from this plot has been nearly doubled, and instead of yielding at the rate of 700 lb. of cacao per acre, it now yields 1,296 lb. It is too early yet to say whether by making the smaller application, the high yields of the other mulched plots will be reached and maintained.

The nitrolim (calcium cyanamide) plot continues to maintain the increased crop produced after the application of this manure.

ON THE GENETICS OF CRINKLED DWARF ROGUES IN SEA ISLAND COTTON.—Part 2.

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In Part 1 of this study,* the F_1 and F_2 results were given of the cross Sea Island by Rogue, together with a general description of the rogues. It was suggested that the rogue may be considered as a retrogressive mutation from Sea Island, due to the loss of a single factor.

THE F_2 GENERATION.

On examining the progeny of plants which were Sea Island in appearance in the F_2 generation, it was found that there were two types of behaviour, (a) families which bred true to the Sea Island character, (b) families which segregated into Sea Island and Rogue. In all, sixty-eight families were grown. Of these twenty-two families proved to be pure Sea Island, while the remaining forty-six families were heterozygous.

*On the Genetics of Crinkled Dwarf Rogues in Sea Island Cotton. *West Indian Bulletin*, Vol. XVI, No. 1, p. 82.

TABLE I.

No. of family.	Sea Island.	Rogue.	No. of family.	Sea Island.	Rogue.
1	20	0	13	23	0
2	70	0	14	17	0
3	24	0	15	9	0
4	39	0	16	40	0
5	16	0	17	10	0
6	31	0	18	50	0
7	12	0	19	39	0
8	7	0	20	15	0
9	26	0	21	9	0
10	10	0	22	45	0
11	48	0			
12	11	0	Total ...	571	0

TABLE II.

Families Heterozygous in F_3.

No. of family.	Sea Island.	Rogue.	No. of family.	Sea Island	Rogue.
23	18	6	48	26	7
24	48	13	49	12	3
25	18	5	50	8	3
26	11	2	51	4	1
27	21	4	52	2	2
28	15	8	53	15	3
29	19	10	54	18	6
30	4	2	55	8	7
31	5	3	56	9	3
32	15	5	57	14	5
33	6	2	58	8	3
34	4	3	59	19	6
35	5	2	60	43	12
36	25	12	61	27	13
37	10	7	62	34	14
38	27	3	63	16	4
39	20	4	64	9	1
40	15	5	65	38	13
41	3	2	66	17	6
42	11	1	67	8	6
43	11	4	68	24	7
44	12	2			
45	12	2	Total ...	731	240
46	16	3	Highest		
47	21	5	expectation	728	243

It was stated in Part 1 of this paper that it is extremely difficult to secure self-fertilized seed of the rogues, owing to their great liability to boll-shedding. The parental rogues have bred true for four generations, however, with absolutely no variation in morphological characters. Three families were grown in the F_3 generation. As will be seen from Table III below the progeny consisted of rogues only.

TABLE III.

Families pure to the Rogue character in F_3.

No of family.	Sea Island.	Rogue.
69	0	31
70	0	15
71	0	52
Total	0	98

It is clear from the results of the third hybrid generation that there is a genetic difference between Sea Island and Rogue, and that this genetic difference is inherited in simple Mendelian fashion. The progeny of the peculiar rogue referred to in Part 1 of this paper, which took on the Sea Island character in its later stages of growth, showed that the plant was a normal heterozygote, giving thirty-nine Sea Island to sixteen Rogue in F_3. The economic importance of this study lies in the fact that a given strain of Sea Island can easily be purified from rogues by self fertilizing for two generations.

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